THE EFFECT OF HOUSING ON THE BEHAVIOUR OF THE OVER-WINTERED LOWLAND EWE

IMPLICATIONS FOR WELFARE AND HOUSING DESIGN

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DECLARATION

I declare that this thesis has been composed by me and is a record of my own work.

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ABSTRACT

The aim of this project was to examine the effects of housing on the behaviour of the overwintered lowland ewe, to see which if any aspects of this husbandry practice give rise to changes associated with a reduction in welfare, and where possible suggest changes to housing design and management practices which could alleviate this.

To facilitate the discussion of the practical work of this thesis, the role of behaviour in the assessment of welfare is pointed out, illustrating the effects of housing on the behaviour and welfare of other species, along with a brief resume of the nature of sheep housing and the behavioural repertoire of sheep in their natural environment.

The practical work was made up of three main parts. These were:

1. A series of studies on sheep kept outdoors in extensive conditions similar to the environment in which sheep are thought to have evolved, in order to establish a basic ethogram and time budgeting for comparison with later indoor work.

2. A series of studies on sheep kept indoors in conditions typical of farm housing in order to establish changes in behaviour which could be associated with a decrease in welfare.

3. A series of studies on sheep kept in pens modified from previous results to establish whether these modifications could alleviate the welfare problems seen.

The behaviour of the sheep in extensive conditions was found to be similar to that given in the literature.

The main effects of typical housing on their behaviour was a considerable increase in proximity of other sheep, levels of alertness and aggressive competition for resources within the pen, in particular for space to feed and to lie near to a solid barrier or wall. There was also a decrease in time spent feeding and resting seen and in the allelomimicry seen in these activities. These changes are considered indicative of a lack of welfare in housed sheep. By including extra pen edges or walls in the form of solid barriers within the pen and allowing extra space up to $7m^2$ per head many of these welfare problems are alleviated.

While there were many restrictions on the practical work of this thesis, a number of recommendations are made concerning the welfare and design of housing for sheep on the basis of these results.

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CONTENTS

INTRODUCTION

Sheep have been associated with man for a very long time. For example, there is evidence that *Ovis orientalis*, thought to be the ancestor of all European domestic sheep, were hunted and eaten by Lower Palaeolithic man and were among the first animals to be domesticated at least as early as the ninth millennium B.C. by Neolithic man (Clark and Piggott 1965). Although agriculture has altered considerably since then, methods of sheep husbandry have changed relatively little over the years, these animals generally being farmed in conditions similar to their wild state.

However, government incentives to British farmers to produce more food after the second World War, resulted in the increasing intensification of animal production in the U.K. A general trend in this development has been the increasing confinement and housing of animals, with considerable restrictions on their behaviour. Public awareness of this aspect of intensification, initiated by publications such as that of Harrison (1964) and Kiley-Worthington (1977) and the general acceptance of certain changes in behaviour as symptomatic of poor welfare (eg. Dawkins 1980, Sambraus 1981, Broom 1983, and Smidt 1983), has in turn resulted in increasing consumer concern for the welfare of those animals kept in this way, for example such as battery hens (Dawkins 1977), stall housed pigs (Fraser 1975) and crated veal calves (Saville and Webster 1981). As the long term housing of sheep is now becoming more common in Britain, particularly for lowland ewe flocks over the Winter months, similar concern may arise for sheep.

The aim of this project is to examine the effects of housing on the behaviour of the overwintered lowland ewe, to see which if any aspects of this husbandry practice give rise to changes associated with a reduction in welfare, and where possible suggest changes to housing design and management practices which could alleviate this.

To facilitate the discussion of the practical work of this thesis, the role of behaviour in the assessment of welfare is pointed out, illustrating the effects of housing on the behaviour and welfare of other species, along with a brief resume of the nature of sheep housing and the behavioural repertoire of sheep in their natural environment.

Although there is some controvesy as to an exact definition of "welfare", there is sufficient agreement on the general meaning of the term to allow discussion of practical methods of assessing this. The Brambell Committee (1965) suggests that the state of welfare represents "complete physical and mental well-being". It is often easier to define and so measure the lack of welfare, or suffering (Dawkins 1980). Of all the criteria which can be used to measure welfare or suffering (Smidt 1983), only ethologial criteria provide information about mental state. The behavioural indicators are also the only easily observable short term or immediate signs of suffering, for example, often being the first symptom seen of physical injury or illness. Certain behaviours are reliable indicators of aversive stimuli, apart from those of fear and responses to pain. For example displacement activities and stereotypies can be produced under controlled experimental conditions of mild short term or severe long term frustration (Duncan and Wood-Gush 1971 and 1972). The abnormal behaviour can in itself cause physical harm to the performer or associated animals, for example the self mutilation seen in monkeys and cockatoos (Morris 1964) and the biting of others ears and tails in pigs leading to severe wounding (Colyer 1970). A detailed list of the detrimental effects of some mouth based abnormal behaviours is given for a variety of species by Fraser (1980). While these effects may have been responsible for early classifications of these types of behaviour as apparently functionless or maladaptive (Fox 1968 and Meyer-Holzapfel 1968), more recent physiological investigations have shown that they are associated with increased secretion of endogenous opiates, and so may have a coping function (Wiepkema, Broom, Duncan and van Putten 1984 and Cronin 1985). Their appearance can therefore be considered as indicative of conditions requiring special, continual and often increasing attempts at coping, which in extreme cases can cause physical harm, and hence where the animal can not be regarded as being in a state of adequate welfare. The existence of other forms of abnormal behaviour such as vacuum and redirected activities supports current theoretical models of motivation which suggest that behaviour is not primarily a goal orientated activity, but rather a system for providing specific sets of neural feedback (Hughes and Duncan 1988), providing a theoretical framework for the idea that the animal may suffer if unable to actually perform a behaviour rather than simply suffering if the usual goal of that activity is not attained. On this basis the behavioural assessement of the state of welfare of an animal requires knowledge of its full behavioural repertoire, which for sheep is most likely to be expressed in their natural environment.

Sheep are found surviving in a wild or feral state in many areas of the world, making use of habitat in a variety of climatic zones and of a diverse topographical nature. However, they generally find their ecological niche in temperate to arid regions with open sloping grassland, and their behaviour has developed, as any other aspect of physiology, in order to enable them to be successful in evolutionary terms within such an environment (Geist 1971).

There have been few detailed studies of the general behaviour of sheep in their natural surroundings, possibly due to the difficulties of access and inhospitability of these areas. The two most comprehehensive reviews are those of the classic studies of wild Bighorn, Stone's and Dall's sheep in American mountain ranges (Geist 1971) and of feral Soay sheep on the Scottish island of St.Kilda (Jewell et al 1974). In some extensive agricultural systems, such as those of the Australian range and British hill farming, similar conditions arise and these have also been used to provide information on the natural behaviour of sheep (eg. Hunter and Milner 1963, Hunter 1964, Arnold and Dudzinski 1978, Lawrence and Wood-Gush 1985). Behavioural data on sheep has also been gathered as an adjunct to other information, particularly on grazing behaviour from studies on the utilization of pasture, and in the relatively few instances where the experimental conditions are not especially restrictive or artificial, this may also be useful (eg. Hughes and Reid 1951 and Squires 1974).

The aspects of sheep behaviour relevant to this thesis are those concerned with normal daily activities and the role of the environment in these, as it is in these areas that housing is most likely to affect their behaviour. Previous work is mentioned and a general summary of this is attempted. However, the various studies are very diverse in nature and some are anecdotal in mentioning general traits and tendencies, making any detailed conclusion difficult. Secondly, factors found to significantly affect these behaviours are listed, giving some insight into the variety in the results of previous work and pointers towards the practical details which had to be considered in the planning of the practical work and interpretation of the results of this thesis.

A few authors have measured time spent in the major activity patterns of sheep kept in conditions which can generally be said to reflect those of their natural environment. For example figures given for hours spent grazing per day range from 7

(Doran 1943), 8-10 (Hughes and Reid 1951), 9-12 (England 1954), 9-10 (Arnold 1962), 4-5 (Squires 1974) to 7-10 (Arnold 1982). Time spent standing was given as 3½ hours by Hughes and Reid (1951) and as 2½-4 hours per day by England (1954). England (1954) found time spent lying to be 3½ hours per day with 9-10½ hours per day spent ruminating and Hughes and Reid (1951) found time spent resting and ruminating to be between 9-12½ hours per day. Squires (1974) quotes time spent resting as between 5½-8½ hours per day. Gluesing, Balph and Knowlton (1980) quote percentage daily time spent over an observation period of 13 hours in the Summer for various activities. An estimation of time spent in hours per day can be calculated from this. For grazing this ranges from 6½-8, for lying this averages around 2 hours per day, for standing around 1 hour per day, for walking around 1 hour per day, for investigatory activity around half an hour per day, and for sleeping and in encounters with other sheep this comes to less than half an hour per day.

The activity categories used by various authors are not mutually exclusive, and there is considerable diversity in the nature of the classifications and methods of calculation used in the various studies. While direct comparisons cannot be made about the precise amounts of time spent in each activity because of this and also due to differences in observation and sampling methods, some general conclusions can however be drawn about the daily behaviour of sheep in such conditions.

Most of the daylight hours are taken up with alternate bouts of grazing and lying ruminating and/or resting. Grazing bouts occupy from half to two thirds of this time, and are generally made up of two main sessions; one in the early morning from dawn and the other from late afternoon until dusk (Cory 1927, Hughes and Reid 1951, Arnold 1977, and Arnold and Dudzinski 1978). There is often a third obvious session of grazing around midday. Considerable allellomimicry is found in the transitions between grazing and lying (Hughes and Reid 1951). When lying, rumination is usually seen at the beginning of a bout, with the sheep appearing reasonably alert; the animal then becomes more drowsy, and is often described as lying resting and ruminating. Eventually, rumination tails off and after a spell of lying resting, a final short burst of appearing more alert and often ruminating also is seen before resuming grazing (Arnold 1982). Time spent grazing and lying vary inversely with each other and with the nature of the pasture as does the distance covered (eg. Cresswell 1960).

Grooming behaviour is never mentioned, although as pointed out by Geist (1971), body care is probably managed through scratching and with the help of small birds, grooming in the usual fashion of other terrestrial ruminant mammmals being impractical for sheep due to the nature of the woolly coat.

It is generally accepted that use of environment in terms of social spacing by sheep depends on many obvious factors such as forage distribution, topography, weather and group demography and such factors have been examined in detail by Arnold and Maller (1985).

While grazing the flock are seen to move within their available space in a predictable manner, such that the sheep can be found in a particular part of their range at particular times of the day. There are specific areas used for lying which differ in site chosen to lie during the day and for camping during the night. When lying resting the sheep come much closer together than when grazing, and even closer to lie at night. The areas chosen for camping seem to be selected on the bases of a dry bed underneath and a clear view rather than for physical aspects of shelter fron the wind, although often a fence line or the brow of a hill may be used in this way, the sheep lying along the fence or just below the brow of the hill, and it should be remembered that the scraping and use of small hollows could provide considerable wind shelter. Posture when sleeping is related to thermoregulatory activity and the insulation properties of various parts of the fleece (Geist 1971).

Sleeping has been examined in particular detail for a small sample of sheep by Ruckebusch (1972), who found them to spend some 16 hours of their day awake, drowse for 4 hours, slow wave sleep on average lasting for 3½ hours and REM sleep taking a total of 43 minutes.

The social behaviour seen in the field is largely cohesive, with overt agression generally not seen unless competing for a very restricted and desirable resource such as supplementary feeding (eg. Arnold and Maller 1974). The basic social structure seen in a variety of breeds and environments appears to be the same (Scott 1945, Hunter and Milner 1963, Shackleton and Shank 1984, Geist 1971 and Jewell *et al* 1974). Briefly, the sexes segregate into completely separate flocks, with the ewes forming groups also containing young, immature males of commonly 20-30 individuals, and the rams forming smaller and less stable bands (Geist 1971, Jewell et al 1974). The ewe flocks contain a high number of related individuals as the ewe lambs tend to stay with their dams and restrict themselves to a particular area of home range (Geist 1971 and Lawrence and Wood-Gush 1985), although Lawrence and Wood-Gush (1983) found ewe lambs occaisonally forming groups separate from the older ewes in Winter. This results in often inseparable interactions between breed, environment and maternal influence and learning when attempting to analyse dispersal of animals (eg. Lawrence and Wood-Gush 1985).

Some details of postural indication of imminent aggression are given by Geist (1971), largely during inter-male competition during the rutting season, but are also relevant to other situations. Briefly, these are head lowering, with vertical or tucked position of the muzzle, ears flattening and stamping of the ground with a foreleg.

While many general remarks such as those above can be made about the behaviour of sheep in their natural environment, it is apparent from the diversity in the literature that a great many factors affect the detail of these animals' daily routine of activity. A number of these have been evaluated for a few behaviours, notably grazing and feed intake, dispersal, socialization, use of shelter and movement. The factors can be divided into three main categories. These are those concerned with the individual (such as breed, sex, age, learning and experience including maternal influence, and physiological state eg. pregnancy, whether shorn or not, disease, body size, presence or absence of horns), those concerned with the social environment (such as group demography in terms of social structure, individuals familiarity, and effects of social dominance relationships, and group size including the effects of isolation and social facilitation) and physical environmental factors (such as season, weather, daylength and particularly pasture topography, plant distribution and nutritive quality). Due to the nature of many of these factors there will be instances in which it is difficult to separate the effects of interractions between them, although some studies attempt to look at this directly (eg Key and MacIver 1980 and Shillito-Walser, Willadsen and Hague 1981). The effects of these factors are outlined below, on the basis of which aspect of behaviour they affect. Again, not all of these behaviour categories are independent, as various studies classify activities differently. For example, socialization and dispersal behaviour will have some effect on grazing behaviour, and it is often difficult to separate the two latter activities.

A variety of individual factors have been found to affect grazing behaviour. For example, breed ((England 1954, Key and MacIver 1980 and Gluesing, Balph and Knowlton 1980), maternal influence (Key and MacIver 1980), pregnancy (Tribe 1950), disease such as facial eczema (Keogh 1975) and age (Lawrence and Wood-Gush 1985 and Gluesing *et al* 1980). Social factors found to affect grazing are group size, showing the influence of stocking rate (Lynch and Hedges 1979) and of social facilitation (Tribe 1950). Strong allellomimetic effects are remarked on by Scott (1945) and Baskin (1971). Apart from the obvious effects of weather and aversive conditions requiring the animals to seek shelter stopping grazing (eg. Geist 1971 and Hunter 1964), other environmental factors such as season affect grazing (Geist 1971 and Keogh 1975). Arnold (1982) found that 58% of the variation in grazing time could be accounted for by the weather. However no study has yet analysed how much of this effect is due to daylength, temperature and prevailing weather, and the consequent state of forage availability and nutritive quality. Studies have shown the direct influence of pasture conditions eg. Crofton (1958) on pasture varying in nematode infection levels. The strength of this rather obvious effect of pasture conditions on grazing behaviour was such that Dudzinski *et al* (1978) were able to predict forage conditions from measurements of grazing behaviour. Group movements during grazing were found to vary with the height of the forage offered by Lawrence and

Wood-Gush (1982) comparing the behaviour of lambs grazing stubble turnips or rape. Key and MacIver (1980) found interacting effects of breed and maternal influence, and Lynch and Hedges (1979) examined the effects of paddock shape, fence type and stocking rate.

The physiological factors regulating feed intake in sheep are reviewed by Houpt and Wolski (1982) and Wood-Gush (1983). Individual factors found to affect feed intake behaviour and diet selection are early experience (Arnold and Maller 1977, Foot and Russell 1978, Lobato and Pearce 1980 , Zenchak, Zenchac and Anderson 1974 and Lynch, Keogh, Elwin, Green and Mottershead 1983), shearing (Arnold 1976) and body size (Lobato and Beilhartz 1979). Isolation and confinement in metabolic cages are associated with a decrease in feed intake, possibly due to a lack of social facilitation, although reduced activity may also play a part (Foot and Russell 1978 and Webster *et al* 1972). Social dominance also affects feed intake, as subordinate animals are prevented from feeding in a competitive situation (Arnold and Maller 1974). Other environmental factors involved are the amount of roughage in the diet (Foot and Russell 1978) and the amount of artificial lighting (Hackett and Hillers 1979).

Breed has been shown to affect association with other sheep (Arnold and Pahl 1967, Arnold et al 1971, Shillito- Walser et al 1981 and Winfield and Mullaney 1973), sheep tending to associate with those of the same breed. Sex also affects this in the same way (Geist 1971, Jewell et al 1974 and Woolf et al 1970). Early experience considerably affects socialization (eg. Hunter and Davies 1963, Shillito-Walser *et al* 1981 and Zito, Wilson and Graves 1978). Familiarity with others also affects social behaviour (eg. Hunter and Davies 1963), and seasonal traits in gregariousness were noted by Lawrence and Wood-Gush (1985). Geist (1971) found both horn and body size to affect the social dominance status, although age was a primary factor. In contrast, Arnold and Maller (1974) found that amongst animals of similar ages body size was not related to dominance status. The inter action of sex and age was noted by Geist (1971) as affecting the social responses of sheep towards potential aggressors, and Shillito-Walser et al (1981) examined the relationship between breed and maternal influence on pair associations of lambs using embryo transfer techniques.

The effects of breed on this were noted by Arnold and Pahl (1967), Arnold *et al* (1971), Cresswell 1960, Winfield *et al* (1981) and Geist (1971). The effect of sex on distribution of animals was noted by Geist (1971) and Jewell *et al* (1974). Lawrence and Wood-Gush (1985) found that maternal influence and early experience contributed to dispersal patterns, and the influence of familiarity with each other also affected this (Hunter and Davies 1963 and Winfield *et al* 1981). Season and forage distribution also caused variation in dispersal patterns (Lawrence and Wood-Gush 1985 and Geist 1971). The likely inter action of breed and individual familiarity was noted by Arnold and Pahl (1967) and the complexity of season, pasture conditions and maternal influence by Lawrence and Wood-Gush (1985).

Hunsaker and Wolynetz (1979) have studied the chronobiological rhythyms of sheep, and it has been found that increasing time spent ruminating decreases the amount of time spent sleeping (Balch 1955), while decreasing the amount of roughage in the diet increases sleeping (Morag 1967). As an increase in dietary roughage is associated with increased rumination, these effects are likely to be linked.

Distances travelled are affected by breed and pasture condition (Cresswell 1960), and social status may affect patterns of movement (Syme and Syme 1975 and Squires and Dawes 1975). Due to the formation of well worn tracks (Geist 1971), it is also likely that previous experience and allellomimicry influence this.

Many intensive animal husbandry systems involving housing certainly do not allow the performance of the full behavioural repertoire, and almost all examples of abnormal behaviour seen in farm animals (eg Fox 1968, Wiepkema *et al* 1983), are seen in conditions involving physical confinement (often in a barren environment), isolation and restriction of feeding (either in terms of time spent and work involved in aquiring adequate nutrition or increased competition). Recent studies have indicated that sheep will respond in the same manner to similar situations (Done 1975, Done-Currie et al 1984, Marsden 1984, Pattison 1985, McMahon 1986, Marsden and Wood-Gush 1986 and Kallweit, Wagner and Smidt 1988). There are however major differences in these experimental housing conditions and those generally found on the farm.

Sheep are overwintered indoors for a variety of reasons, largely to do with land management rather than improving animal production *per se*. Housing the lowland ewe flock over the winter prevents poaching of pasture, allowing early regrowth of grass, This aids the finishing of lambs for a lucrative early market. Removing the sheep can release pasture for cereal growth and allow early access to land for ploughing. While a decade ago this may have been sufficient financial incentive to justify the costs of providing sheep housing, recent trends in agricultural policy regarding cereal quotas and land use probably make this no longer viable. For some breeds such as Suffolks this facilitates early lambing in January and ewes are housed with the lambs for the ensu.ing winter months. The success of this venture again largely depends on filling a gap in the market for early lamb. Housing provides a much more hospitable environment for the shepherd, and considerably lessens the manpower requirement for feeding and checking the sheep, a considerable boon for smaller flocks where labour is a major part of running costs. While it has been pointed out that housing could be considered as improving the welfare of the sheep by protecting them from the often aversive winter weather conditions and allowing a reliable food supply (Wood-Gush and Marsden 1986), this is rarely the primary reason for housing of sheep, and publications dealing with the practicalities of sheep housing reflect this by not mentioning the nature of the animal at all (eg Bryson 1984). Commonly the sheep are penned within a standard farm shed. Many varieties of shed are used, as the sheep are not housed all year round and even a shed erected primarily for sheep will be used at other times of the year for other farm enterprises, eg storage of hay, straw, or grain to be sold off the farm. Adequate ventilation without draughts at animal level is particularly important to prevent a buildup in respiratory diseases, and so buildings with walls incorporating a top half of semi permeable construction, such as yorkshire boarding for example, are recommended. As a solid floor is generally needed to enable the building to have a more flexible use, a concrete or hardcore floor is common, and the animals usually bedded on deep litter straw for convienient drainage and dung disposal. Pen layout and size is largely determined by feeding method. This is usually *ad lib* forage such as silage or hay, dispensed from a tractor and trailer driven through the shed. This necessitates the feeding face or troughs to be arranged in a straight line, and in parallel lines a tractor's width apart to increase the efficiency of feed dispersal from both sides of the trailer simultaneously. Supplementary feeding is usually given in the form of concentrated mix either sprinkled on top of the forage or put manually into small troughs within the pens. As sheep will pack closely together to feed when supplements are given, the length of feeder required per sheep is calculated from this minimum amount, giving recommendations of 4-6 inches per head (eg. ESCA Farm Buildings

Topics 1975). As it is a generally accepted code of practice that animals require enough room to accommodate their body size and to turn around, the minimum recommendations for space for housed sheep is 2 square meters per head. A combination of these three factors results in the sheep being penned in groups of around 30 in rectangular pens along the sides of the shed in two rows separated by the feeding corridor. A review of further practical details and some examples of purpose built sheep housing is given in the Scottish Farm Buildings Investigation Unit's leaflet "Sheep Housing in Progress" (1986). On many farms however, accommodation for sheep is generally not purpose built and use is made instead of existing farm buildings, where the major factors considered regarding adaptation or suitability are the provision of adequate ventilation and access for ease of feed distribution. This results in a great deal of variation in detail of the nature of sheep housing in practice.

Work developing a housing system incorporating ideas on the behavioural assessment of welfare has been carried out successfully with pigs. Stolba and Wood-Gush (1984) describe their method of identifying environmental features required for the expression of full behavioural repertoire of pigs kept in an enclosure containing all aspects of the environmental conditions in which pigs are thought to have evolved. By progressively reducing the physical complexity of these features, the key elements allowing the continued expression of the behaviour associated with these were identified, and incorporated into a design for a practical housing system, which also kept the pigs in the kinds of social groups that they formed themselves in free ranging conditions (Stolba 1982). However, there are a number of differences between pigs and sheep which are reflected in the difference in approach required here. The effect of housing on the behaviour and welfare of pigs had already been identified (eg Fraser 1975), and although an increase in abnormal stereotyped behaviour and aggression has been described in sheep penned individually for research purposes (Done-Currie at al 1984 and Marsden and Wood-Gush 1986), there are no details of their behaviour in typical farm housing. The social structure of sheep is not so grossly changed with sheep by farming practices, and while sheep do use certain areas for particular activities, they are not as specific in this as pigs.

The practical work of this thesis consists of observations of the behaviour of sheep overwintered in a variety of environmental conditions. Firstly, observations were made on sheep kept in conditions resembling those in which they are thought to have evolved, in order to provide details of their full normal behavioural repertoire and to determine which environmental features are relevant to this. Secondly, sheep were observed in conditions representing typical farm housing practices, in order to evaluate specific areas of behavioural change and welfare concern. As far as was practically possible an attempt was made to control for those factors noted in the literature as affecting the behaviour of sheep. Thirdly, some experiments were set up to investigate particular features identified as potential areas for the improvement of housing systems.

EXPERIMENTAL SECTION

GENERAL MATERIALS AND METHODS

The experimental work is divided into four major sections :

(1) In which the animals are outdoors at pasture in conditions resembling their natural environment.

(2) In which they are housed indoors in typical farm husbandry conditions.

(3) In which the environment has been manipulated to study the effects of particular factors.

(4) In which the animals are housed in pens modified according to the results of these previous sections.

As much of this experimental work uses similar animals, husbandry methods and observational techniques, this General Materials and Methods section is included to avoid repetition of common details. Within each of the experimental divisions, experiments or sets of observations are described in chronological order. An account is given of the materials and methods specific to each set, including a brief outline of the general aims and followed by the results for that set. The results are briefly discussed as they are presented, providing the basis for a General Discussion Section, which answers a number of questions about the behaviour of the sheep, drawing on data from various sets of observations and involve comparisons between the major experimental sections and looks at these findings in the broader context of the issues mentioned in the Introduction.

The experiments and sets of observations described in this Experimental Section have a number of details in common. Grey-faced ewes, (Border Leicester cross Blackface) from the same flock were used throughout. All of the sheep were familiar with each other and all had previous experience of over-winter housing. In every group ages ranged at random from 2-7 years, and all observations were made between December and April, during the period when most of the sheep were in the last 50 days of gestation. Those animals kept outdoors were fed ad-lib hay and those kept indoors were fed ad-lib silage and all were given a concentrate supplement of E.S.C.A. (college of agriculture own brand) nuts at the levels recommended to maintain condition. Their husbandry routine involved two visits per day, one in the morning to replenish the hay or silage and one in the late afternoon giving their concentrate feed. The exact times of these visits varied depending on other farm business. The indoor sheep were given fresh bedding approximately once a week.

The paddocks used for observations on sheep kept outdoors varied considerably, and are described in detail individually later.

The same shed was used for all of the observations on housed sheep. It was a general purpose protected open ridge farm shed. A diagram is given later. The walls were brick to a height of 2.7 metres with 0.5 metres of Yorkshire boarding from this to the corrugated tin roof, 3.2 metres high. A few of the concrete roof supporting posts stuck out some 6 inches or so into the pens. The floor was concreted, and the sheep were all bedded on deep litter straw. There were three main doors at one end of the shed and one at the other. This single door was usually kept closed, and the other three left open. The centre door of these three was directly opposite the single door these being at either end of a central passageway. The two beside this centre door were in walls forming pen boundaries, and were blocked by a 1 metre high 5 bar gate. This was further reinforced by a solid wooden gate of the same height for the side on which the sheep used for observation were kept. All of the pens used were on this same side of the shed, separated by solid hurdles, 0.75 metres high. The side of the pens next to the central passageway was used as the feeding face. This was made up of a 0.75 metre high slanted metal bar type of cattle feeding barrier, the base of which was 0.5 metres off the floor. A 20cm wooden kicker board and a plank tied half way between the top of the board and the bottom of the cattle feeder bars prevented the sheep escaping, and they fed through the gap between the kicker board and the plank, on silage forked onto the floor of the central passageway. The concentrate feed was given sprinkled on top of the silage, and also into a couple of low (6" high) wooden 'V' type troughs lying in the pen in an attempt to allow all of the sheep to feed together.

Experiment headings give the year in which they were done, and a brief description of the nature of environment and, where appropriate, the specific purpose of that experiment. Generally, experiments, in which there was some degree of control over the animals with modifications to the usual husbandry practices, could only be done during a two to four week period between the end of tupping and the beginning of housing. This meant that such experiments were done over the end of December and the beginning of January, and these are dated as 1984/5, 1985/6 or 1986/7. The exact amount of time available depended on the time chosen to start tupping, the weather and grass availability as determining the need for housing, and shed availability as determined by shed use for other farm enterprises. Longer term observations of sheep kept both indoors and outdoors for comparison were made throughout the normal housing period from early January until lambing in late March / early April. These groups were generally made up of animals on other (non-behavioural) experiments and so no control on animals or conditions was possible.

Any one group of animals over a given period was observed in order to record the maximum amount of information about their behaviour possible within the limits of time and other practical considerations. This generally took the form of scan sampling with either interaction samples or focal animal studies (see appendix C for details of these techniques) during the intervals between scans. Such sets of observations were then sampled to provide data to answer a variety of questions about the behaviour of the sheep and their relationship with their environment. Each of these sets of observations is given a reference number so that the source of the data used to answer a particular question, or referred to in general discussion, can be identified. This reference includes the last two digits of the year and a note of whether the sheep were housed or at pasture. For example, 85 OUT refers to observations made over the period January to April 1985 on sheep kept outdoors, and 85/6 IN refers to observations made during December 1985 and January 1986 on sheep kept indoors.

The scan samples were recorded by drawing the position of each animal onto scale diagrams of the enclosure areas. A single line was used to represent the spine, bent if required to show the direction of the neck and head. An arrowhead marked the direction of vision. For recording purposes, distances were estimated by the rule of thumb that one sheep length was approximately one metre, and the known distances already measured between relevant landmarks, using a graduated stick in the same manner as an artist to assess the relative distances between animals and environmental features. Each individual's identity and activity was noted, using a series of simplified behavioural categories in comparison with the full ethogram given in Appendix A. The focal animal studies were used to gather details of behaviour such as posture, common sequences and nature of interactions with environmental features. The interaction samples were used mainly to record aggressive behaviour, noting the numbers of both threats and butts, the individuals involved as instigator and recipient(s), the area in which the interaction occurred and where possible the resource involved, the outcome of the interaction in terms of displacement of individuals and subsequent use of resources and any adjunctive activities, such as urination, defecation or scratching.

The distances and orientation between sheep were measured as shown later (Figure 2.4). The mid-body point was used for distance measurement, so that this could be consistent for all orientations. The line of the spine was used for orientation measurements. The angle of orientation of one sheep to another was taken as the minimum angle through which one sheep would have to turn in order to be parallel to and facing in the same direction as the other. The angle of orientation of each sheep to the other within any pair of sheep is always the same for each member of the pair. The minimun angle is zero, when the sheep were parallel, and the maximum is 180 degrees. Figure 2.4 (see later) gives some examples. The area or space occupied by the group of sheep was usually measured by the taut string method as shown in Figure 2.5 (see later). A line is drawn around the group on the scan sample sheet to represent a string pulled taut around it, hence joining up all those members at the extremeties of the group. The area thus enclosed can be measured by superimposition of a fine grid graduated to the scale of the sample sheet, and counting the squares covered by the enclosed area. However, for some of the groups of housed sheep in pens modified by the inclusion of barriers within the pen, this method was not suitable, and a rectangular method was used instead as shown in Figure 2.6 (see later). This is a modification of the taut string method, in which the animals as drawn on the scan sample sheet are enclosed by a rectangle, the sides of which are drawn parallel to the pen boundaries. For ease of comparison with both outdoor sheep and those indoors, the space occupied by the sheep kept in typical pens was measured using both methods.

For all forms of recorded data the date, time of day, and weather details (sunny, bright or overcast : drizzle, slight rain, heavy rain, mist or fog : wind speed approximation on the Beaufort scale : ambient temperature) were noted, along with any unusual circumstances, such as disturbances or changes in the use of the surrounding areas.

Statistical tests were carried out as described in Siegel (1956) and Lehner (1979).

OUTDOOR SHEEP IN EXTENSIVE ENCLOSURES

AIM

The aim of this set of observations was to record the behaviour of sheep kept outdoors in extensive conditions, in order to record a basic ethogram for comparison with that of intensively housed sheep, and to establish the relevance of the available environmental features towards this.

MATERIALS AND METHODS

Three separate populations were used. These are referred to as Knowes, Grange and Woodhouselee respectively.

The first group (Knowes 84/5 OUT) represented typical husbandry conditions for sheep over-wintered at pasture. The second group (Grange 86 OUT) were given a more varied environment separating some of the major features of their natural environment. This was also a much smaller group to enable a more direct comparison to be made with those studied indoors. The third group (Woodhouselee 87 OUT) were similar to the Grange sheep, acting as a repeated sample, as individual preferences and local resource relationships could considerably influence the behaviour of such small groups in such unique conditions.

In all groups the animals used were pregnant Greyfaced ewes between 2 and 5 years old. All were familiar with each other and had previous experience of both in- and out- wintering. The ethogram used is included (Appendix A).

All of the enclosures were mapped using triangulation techniques and a meter wheel. The slope is indicated by dotted contour lines on scale diagrams of the enclosures. As the areas were not large enough to include more than one contour, as given on the relevant Ordinance Survey maps, an approximation was made of lines of intermediate contours at a few strategic points to illustrate the topography of each enclosure. This was done with the meter wheel, meter long sticks stuck into the ground and a spirit level, using the meter high levelled line of sight to find the spot where the ground had risen by a meter at various points along the origonal OS coutour line. Once the distance to each of these spots was measured, they were plotted onto the scale diagram, and joined together to produce the next meter contour line. As the Grange enclosure, was particularly small and mainly flat with a steep rise in one corner, the 'contour' lines represent height above the flat area. Each enclosure was made up of distinctive areas, each comprising a different set of environmental features, and these areas are separated by solid lines and labelled by an encircled capital letter. Other features and these letters are explained in a key for each diagram.

The distances between animals and their orientation to each other was measured as shown in Figure 2.4. The identity and activity of each sheep was noted, being the two major factors most likely to affect any relationship between distance apart and orientation. A note was also made of those instances where one of the pair was thought to be out of sight of the other. Such cases were not left out altogether as if A cannot see B, but B can see A then while the behaviour of B is unlikely to be influencing A, the behaviour of A might well be influencing B.

Some analyses made use of only a sample of all of the available data and the details are given where this occurs when presenting the results.

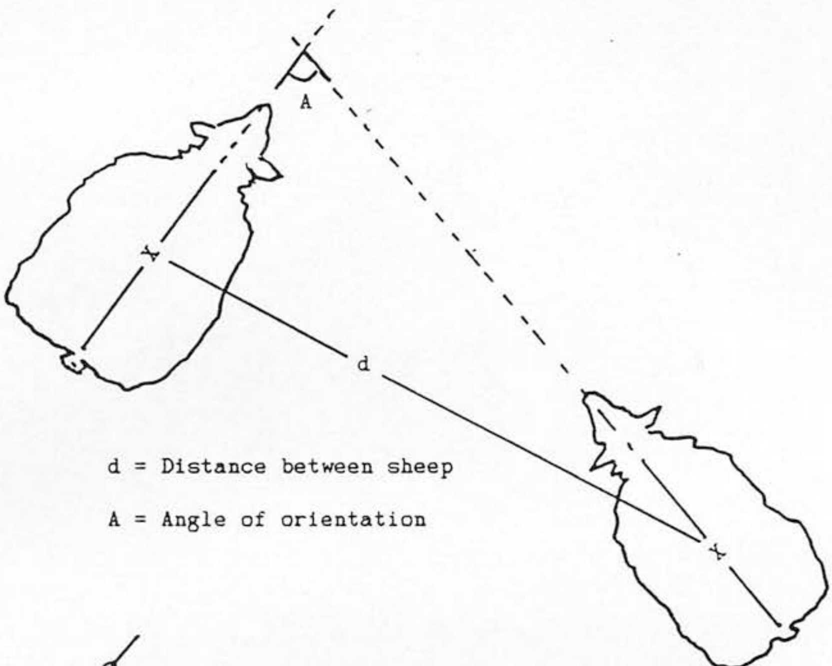
Knowes

150 ewes were grazing 77,600 m^2 (of Italian Ryegrass), giving 52m^2 area/head. This was supplemented with hay fed ad-libitum, and water was freely available from a burn. Twenty of the ewes were individually marked using "Agrimark" spray.

Observations were made during daylight hours over six days at the end of December 1984 and the beginning of January 1985, between 10.30am and 3.30pm. This provided three 20 minute focal animal studies for each of the twenty marked sheep. Half hourly scans of the whole flock gave 66 scan samples. In total 30 hours of actual observation were recorded.

FIGURE 2.4

DIAGRAM SHOWING MEASUREMENT OF DISTANCE BETWEEN AND ORIENTATION



EXAMPLES

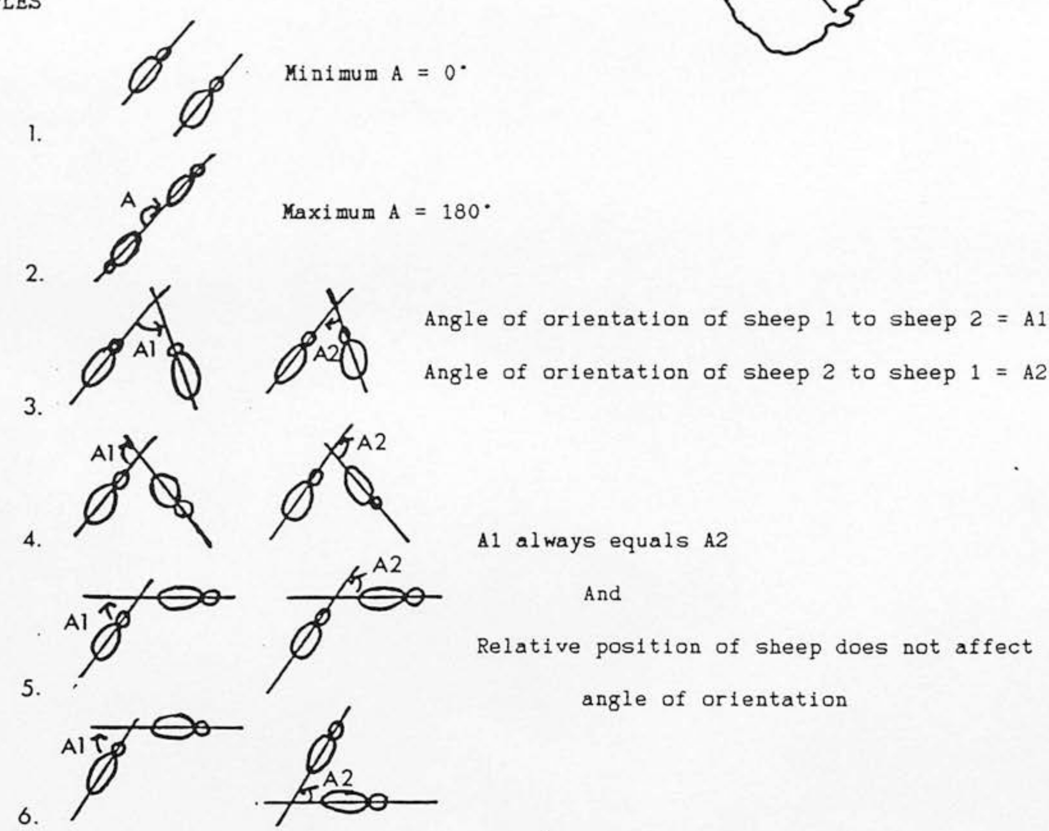
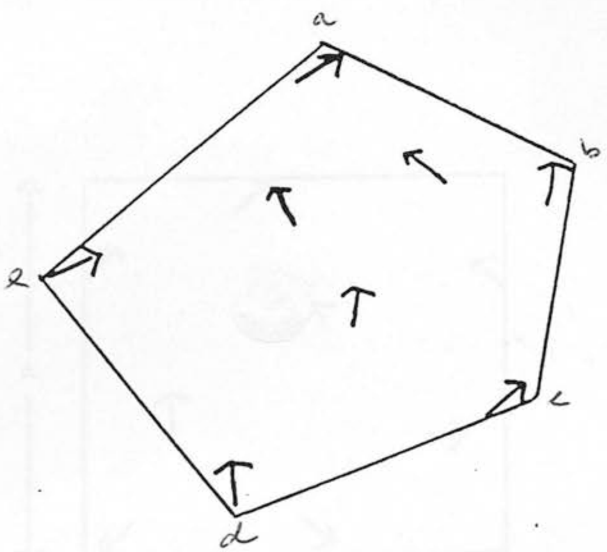


FIGURE 2.5

DIAGRAM SHOWING MEASUREMENT OF SPACE OCCUPIED BY THE GROUP USING THE TAUT STRING METHOD

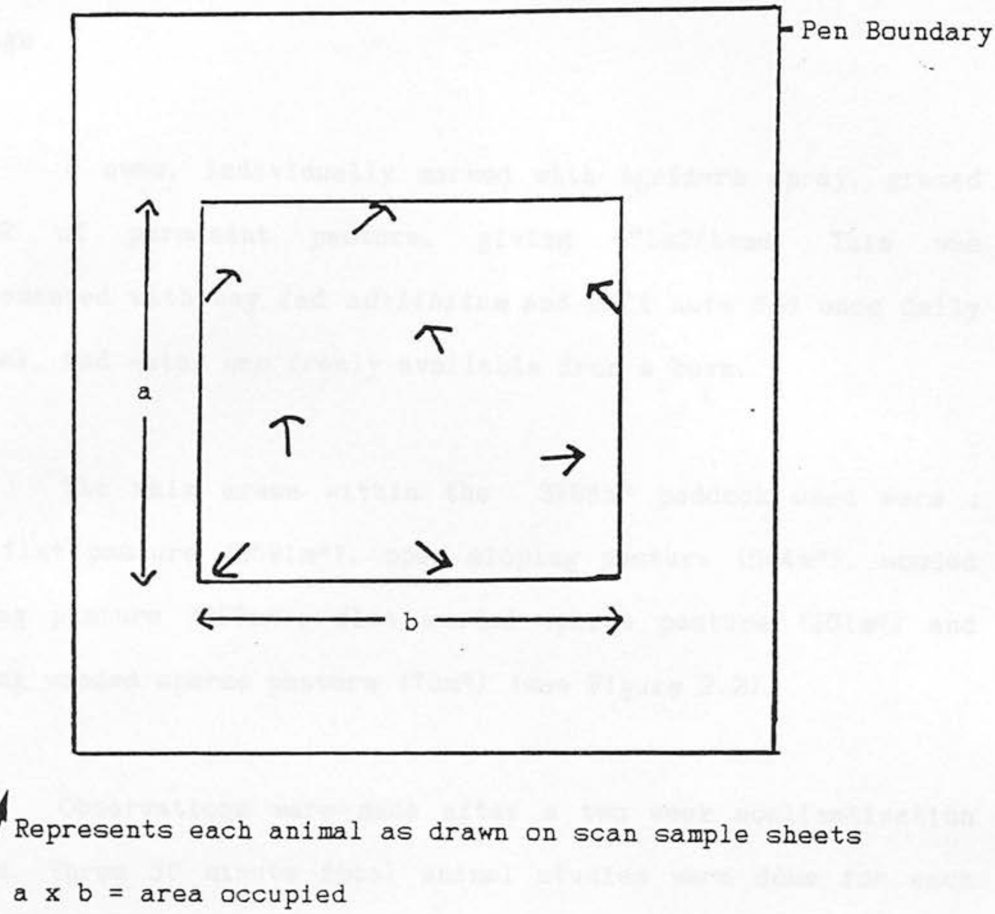


Represents each animal as drawn on scan sample sheets


= area occupied

Figure 2.6

DIAGRAM SHOWING MEASUREMENT OF SPACE OCCUPIED BY THE GROUP USING THE RECTANGULAR METHOD



A scale diagram of the field is given as Figure 2.1.

Grange

8 ewes, individually marked with Agrimark spray, grazed 3768m2 of permanent pasture, giving 471m2/head. This was supplemented with hay fed *ad-libitum* and ESCA nuts fed once daily at dusk, and water was freely available from a burn.

The main areas within the 3768m^2 paddock used were ; open flat pasture (2691m^2), open sloping pasture (504m^2), wooded sloping pasture (252m^2), flat wooded sparse pasture (251m^2) and sloping wooded sparse pasture (70m^2) (see Figure 2.2).

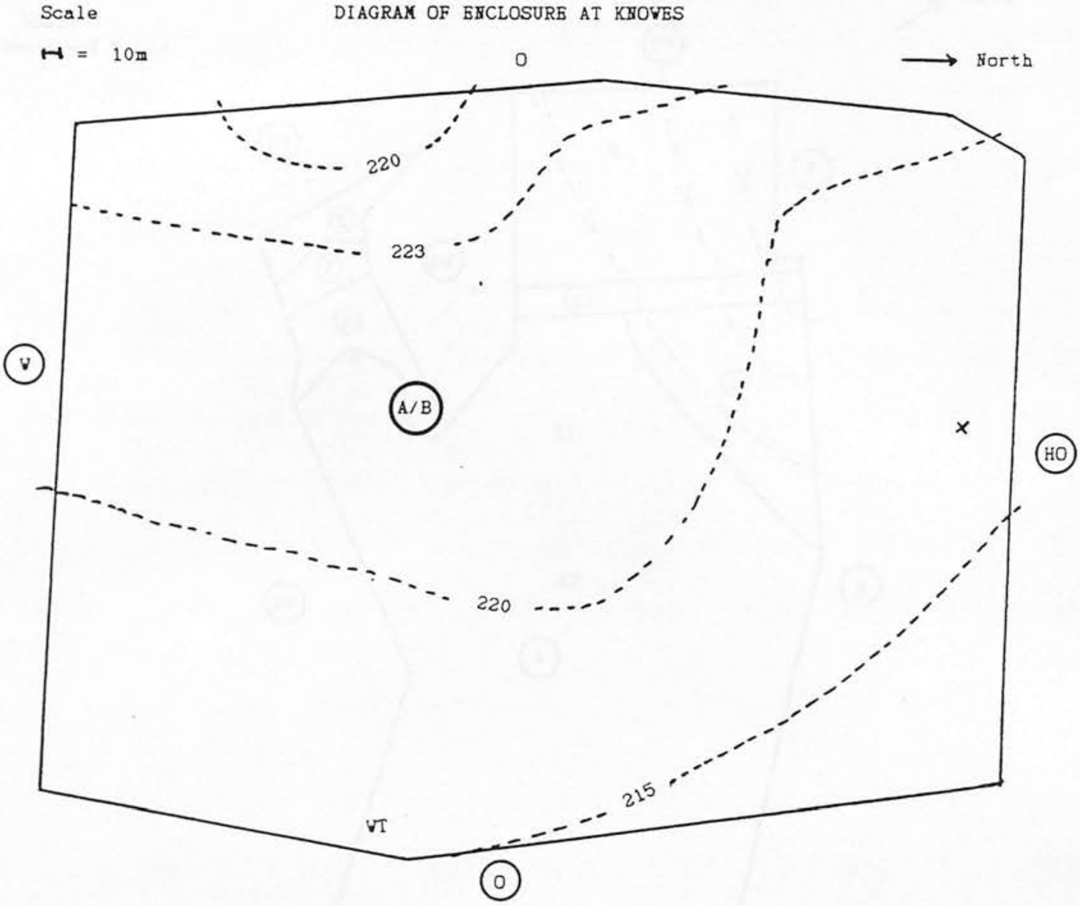
Observations were made after a two week acclimatization period. Three 30 minute focal animal studies were done for each individual and three 24h composite daylight periods from 6.30am to 7.30pm between mid February and mid April 1986 were recorded using half-hourly scans. Overall, 39 hours of observation and 81 scan samples were recorded.

Night observation was attempted using a torch, but this greatly disturbed the animals and so was abandoned. Some casual observations were made over the lambing period, including night lying position and place and time of lambing.

A scale diagram of the paddock is given in Figure 2.2.

FIGURE 2.1

DIAGRAM OF ENCLOSURE AT KNOWES



A/B Gently sloping pasture with scattered flat patches

X Position of Hay rack

WT Position of water source

W Wooded area adjoining field

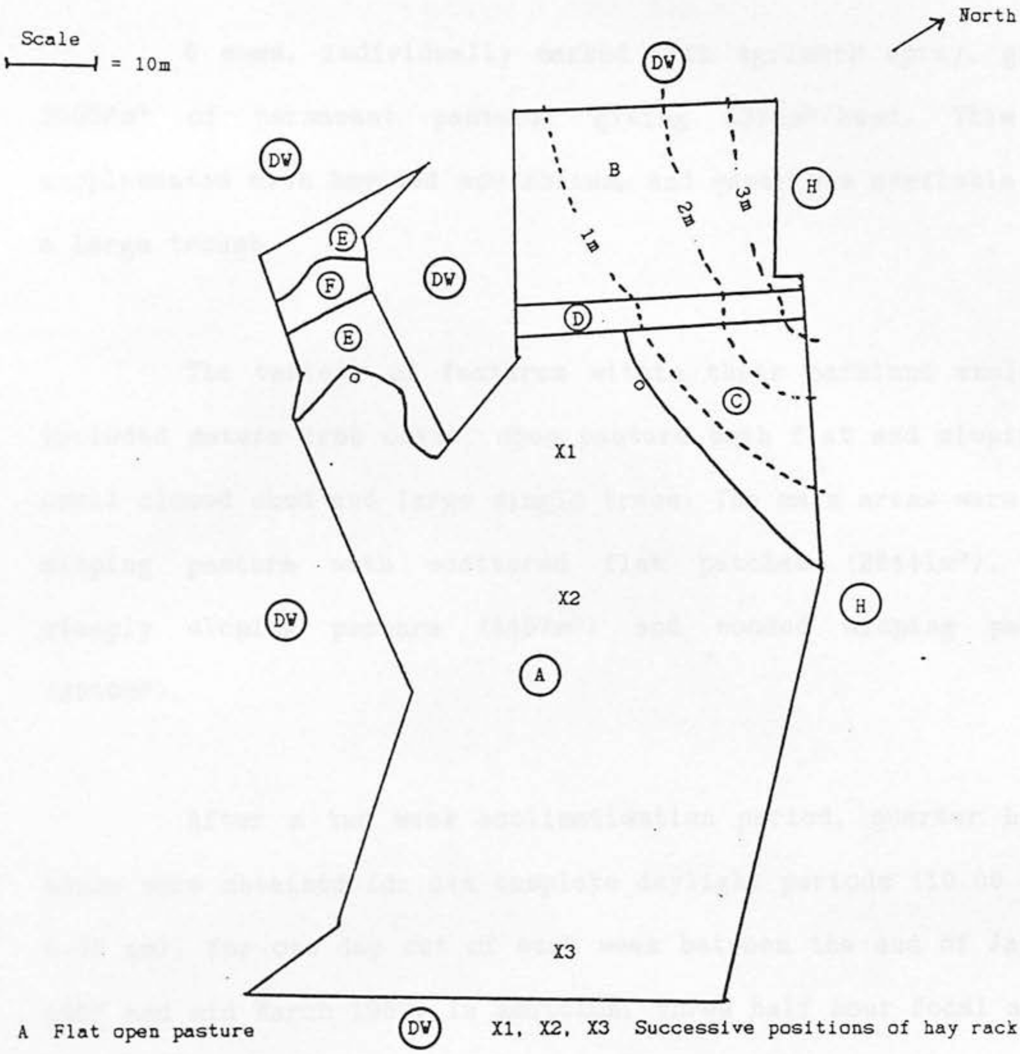
O Open pasture adjoining field

HO Hedge at boundary of enclosure, overlooking open pasture

----- Contour line illustrating slope (in relation to Ordinance Survey (OS) line of 220m)

FIGURE 2.2

DIAGRAM OF ENCLOSURE AT GRANGE



A Flat open pasture

B Steeply sloping open pasture

C Sloping wooded pasture

D Sloping wooded sparse pasture

E Flat wooded sparse pasture

F River, easily fordable water source

H Hedge at boundary blocking sheep view beyond it

DW Dense woodland adjoining field

Boundary of areas within enclosure ———

---- Contour lines illustrating slope

X1, X2, X3 Successive positions of hay rack

o Large single tree

Contour measurements given in relation to flat area = 0 (in metres)

Woodhouselee

8 ewes, individually marked with Agrimark spray, grazed 35008m² of permanent pasture, giving 4376m²/head. This was supplemented with hay fed *ad-libitum*, and water was available from a large trough.

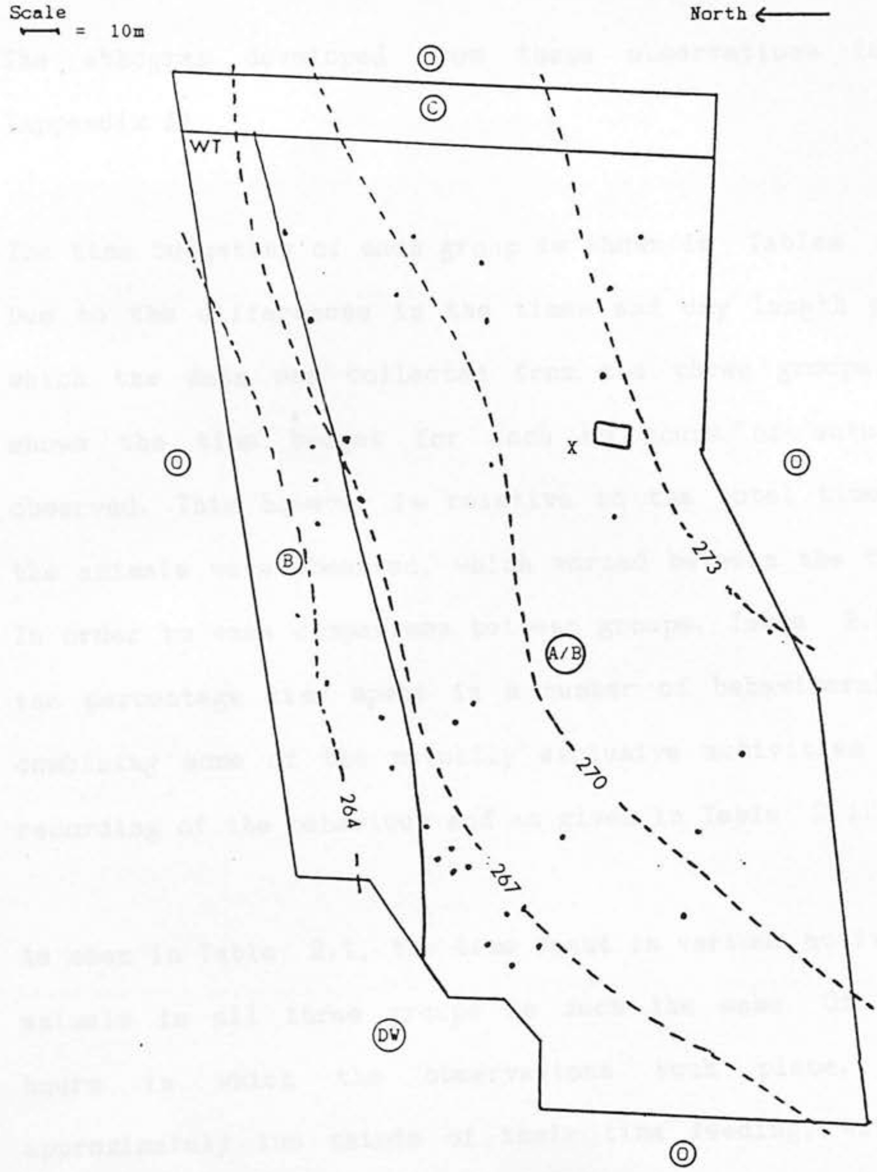
The variety of features within their parkland enclosure included mature tree cover, open pasture both flat and sloping, a small closed shed and large single trees. The main areas were open sloping pasture with scattered flat patches (26441m²), open steeply sloping pasture (4487m²) and wooded sloping pasture (3000m²).

After a two week acclimatisation period, quarter hourly scans were obtained for six complete daylight periods (10.00 am to 4.00 pm), for one day out of each week between the end of January 1987 and mid March 1987. In addition, three half hour focal animal studies were obtained for each of the 8 animals. Overall, 48 hours of observation and 204 scan samples were recorded.

A scale diagram of the paddock is given in Figure 2.3.

FIGURE 2.3

DIAGRAM OF ENCLOSURE AT WOODHOUSELEE



A/B Gently sloping pasture with scattered flat patches

□ Shed

C Sloping wooded pasture

O Open pasture adjoining field

B Steeply sloping open pasture

DW Dense woodland adjoining field

X Position of hay rack

• Tree (large single tree within open area of parkland)

WT Position of water source

Boundary of areas within enclosure ———

---- Contour lines illustrating slope (in relation to OS line of 270m)

RESULTS and DISCUSSION

The ethogram developed from these observations is given in (Appendix A).

The time budgeting of each group is shown in Tables 2.1 and 2.2. Due to the differences in the times and day length periods over which the data was collected from the three groups, Table 2.1 shows the time budget for each as hours of actual activity observed. This however is relative to the total time over which the animals were observed, which varied between the three groups. In order to ease comparison between groups, Table 2.2 represents the percentage time spent in a number of behavioural categories combining some of the mutually exclusive activities used in the recording of the behaviour and as given in Table 2.1.

As seen in Table 2.1, the time spent in various activities of the animals in all three groups is much the same. Of the daylight hours in which the observations took place, they spend approximately two thirds of their time feeding, with one third lying ruminating. This is similar to that given in the literature. It is interesting that animals in the larger group of the Knowes generally spend more time resting and less time alert than those of the two smaller groups, an effect commonly found in social animals and suggested as one of the advantages of increasing group size. Between these, those at the Grange spend slightly more time alert and less resting than those at Woodhouselee. The major

TABLE 2.1

TIME BUDGETS OF OUTDOOR SHEEP; TIME SPENT IN PARTICULAR ACTIVITIES

Activity	Number of scans Knowes (n=20)		Grange (n=8)		Woodhouselee (n=8)	
	Mean per sheep	(±SE)	Mean per sheep	(±SE)	Mean per sheep	(±SE)
Grazing (Z)	28	(±2.8)	31	(±3.1)	73	(±2.3)
Feeding (F)	10	(±1.1)	16	(±1.3)	41	(±1.2)
Lying ruminating (LM)	17	(±1.3)	17	(±1.2)	41	(±0.7)
Lying alert ruminating (LMA)	3	(±1.0)	5	(±1.1)	10	(±1.1)
Lying resting (LR)	5	(±1.1)	3	(±1.1)	7	(±1.2)
Standing alert (SA)	2	(±0.9)	6	(±1.4)	26	(±1.0)
Standing ruminating (SM)	1	(±0.6)	1	(±0.5)	2	(±0.4)
Other (O)	1	(±1.1)	1	(±1.2)	3	(±1.1)

n=group size

Note The total number of scans varies with each group.
For Knowes this is 66 representing 21% of 24 hours
For Grange this is 81 represting 54% of 24 hours
For Woodhouselee this is 204 representing 32% of 24 hours.

TABLE 2.2

TIME BUDGETS OF OUTDOOR SHEEP;

TIME SPENT IN COMBINED ACTIVITY CATEGORIES (%)

Activity	Knowes	Grange	Woodhouselee
Feeding (Z+F)	61	59	56
Ruminating (LM+LMA+SM)	29	31	26
Standing (SA+SM)	12	8	14
Lying (LM+LMA+LR)	30	33	28
Alert (SA+LMA)	8	23	18
Resting (LR)	11	2	3

n=group size

Notes:

1. The sheep stood while feeding, so estimation of total time spent standing should include this also.
2. Figures do not necessarily sum to 100% as the categories (as denoted in Table 2.1) were combined in various ways (as shown by abbreviations for each activity as described in Table 2.1).

differences between these two enclosures is that the Woodhouselee area was larger and much more open, offerring expansive views similar to that of the Knowes enclosure. Thus, it seems that being a member of a larger group or having a more open environment encourages more time resting with less time spent alert. The distribution between grazing and feeding (on *ad lib* hay) is also of interest, as although the relative nutritive value of the pasture was less than that of the hay, the sheep still spent a good two thirds of their feeding time grazing. This is in agreement with other studies which looked in detail at the optimality of foraging (Broom and Arnold 1986) or adequate diet selection of various concentrate feeds available *ad libitum* (Gordon and Tribe 1951). Both studies found that the sheep did not behave in such a way as to maximize intake even when general food availablity was low, neither did they select a diet of concentrates which would enable them to maintain health and bear and rear lambs successfully. So palatability and other factors involved in grazing apart from acquiring adequate nutrition do appear to be important in the time budgeting of sheep.

The time budget data shows that grazing and lying resting or ruminating were the two main activities of these sheep. The pattern of these activities followed the daily cycle often quoted in the literature, as shown in Figures 2.13 and 2.14. These are made up of a sample of two days data from each group. There are three main periods of grazing activity interspersed with periods of lying resting and/or ruminating. These Figures also illustrate the considerable amount of allelomimicry seen in these activities,

FIGURE 2.13

ALLELOMIMICRY AND CYCLILCAL PATTERN OF FEEDING

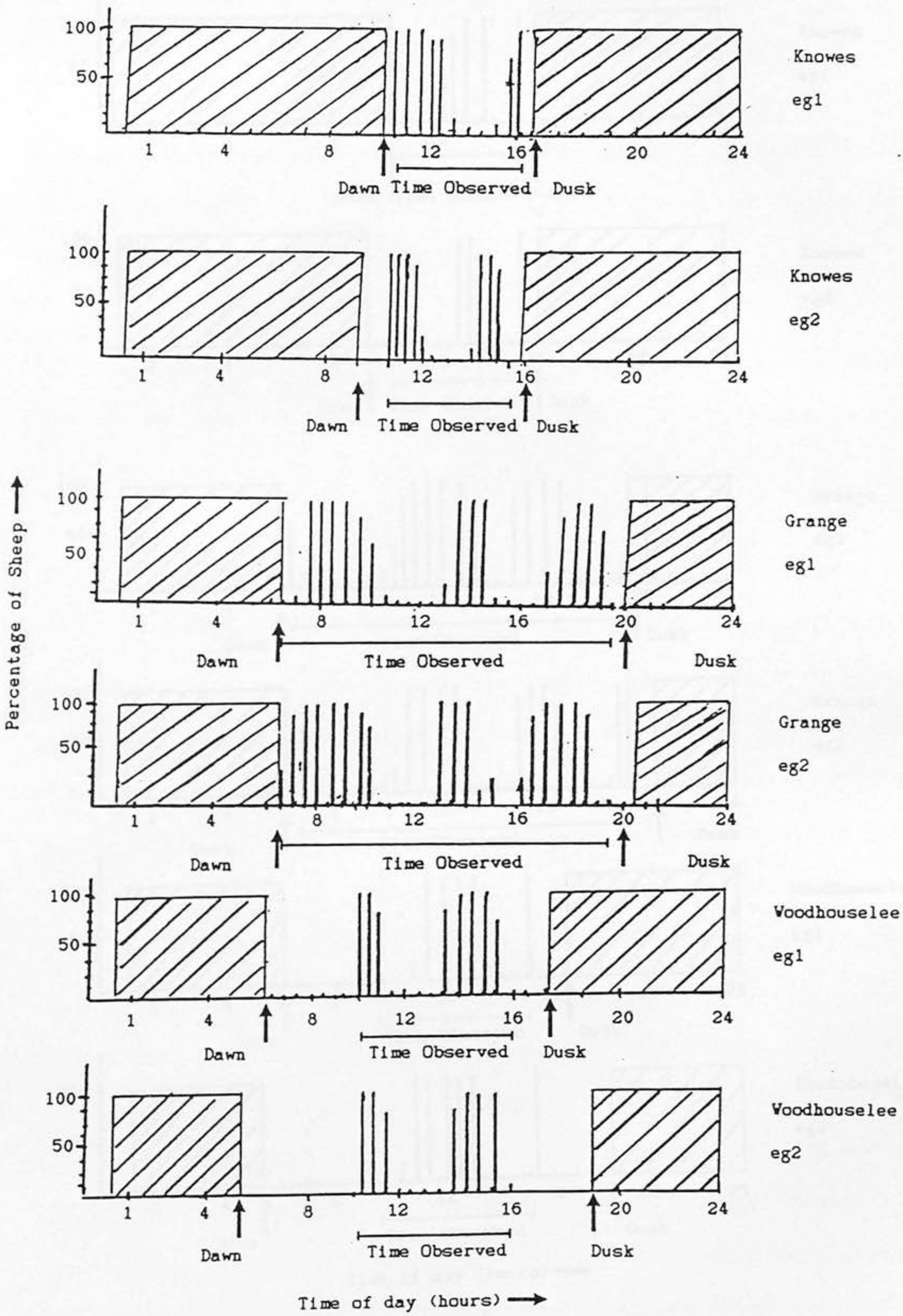
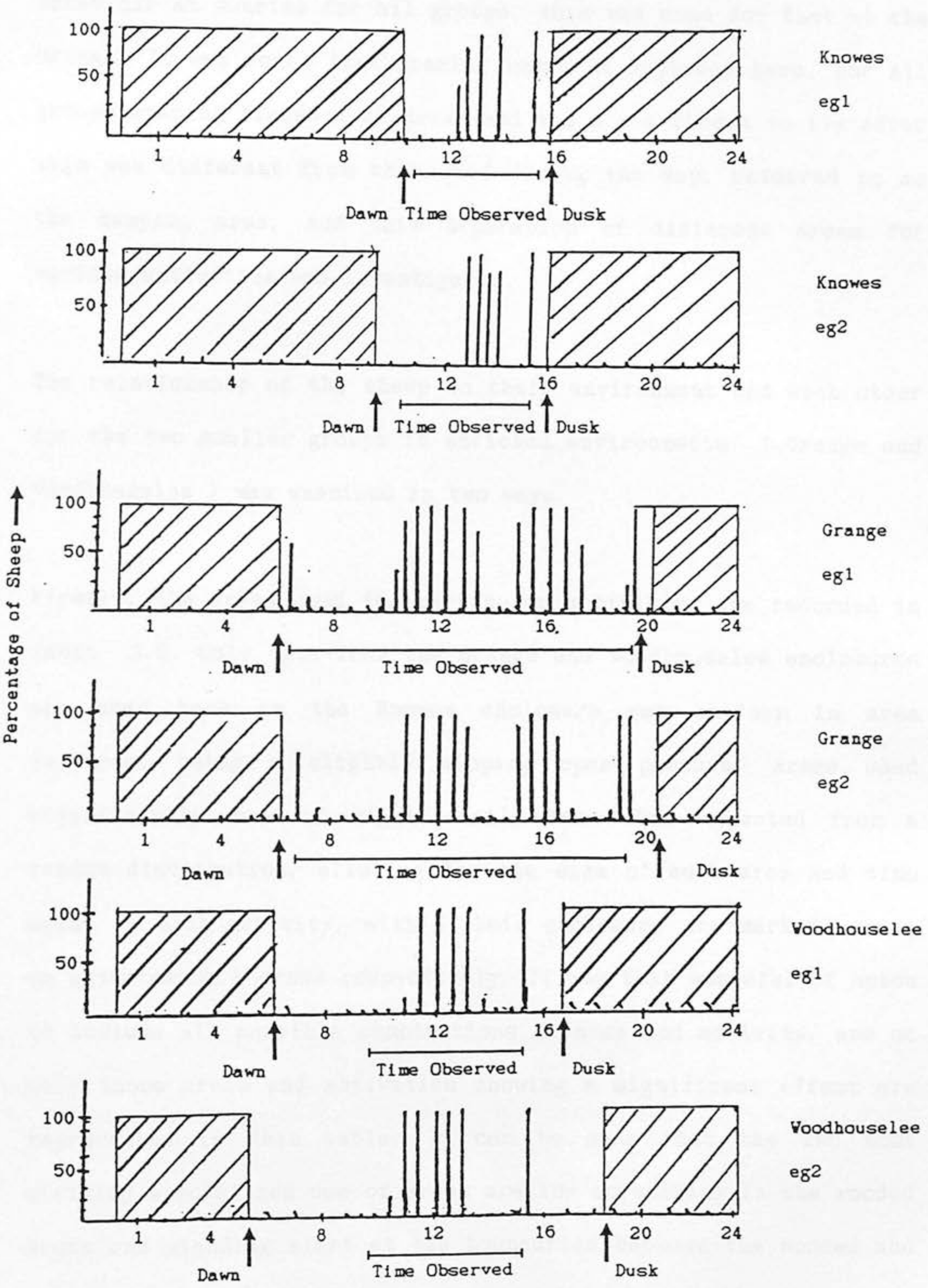


FIGURE 2.14

ALLELOMIMICRY AND CYCLILCAL PATTERN OF FEEDING



and the relationship of the first and last grazing periods to sunrise and sunset. Although it was not possible to monitor behaviour at sunrise for all groups, this was done for that at the Grange. It was found that grazing began at daybreak here. For all groups grazing finished at dusk, and the place chosen to lie after this was different from that used during the day, referred to as the camping area, and this separation of different areas for various activities was investigated.

The relationship of the sheep to their environment and each other for the two smaller groups in enriched environments (Grange and Woodhouselee) was examined in two ways.

Firstly, the areas used for particular activities are recorded in Table 2.3. Only data from the Grange and Woodhouselee enclosures are used here as the Knowes enclosure was uniform in area features, being a slightly sloping open pasture. Areas used significantly more or significantly less than expected from a random distribution, allowing for the size of each area and time spent in each activity, within their enclosure are marked, using an asterisk or a cross respectively. It was felt wasteful of space to include all possible combinations of area and activity, and so only those areas and activities showing a significant effect are represented in this table. It can be seen that the two most striking specialized use of areas are for scratching in the wooded areas and standing alert at the boundaries between the wooded and open areas. It is to be expected that the sheep will make use of trees and logs to scratch themselves. The alertness at boundaries

TABLE 2.3

USE OF ENVIRONMENT; PARTICULAR AREA TYPES USED FOR SPECIFIC ACTIVITIES

Activity	Group	Areas Open pasture chi^2	 Wooded areas chi^2	 Open/wooded boundary chi^2
Grazing	Grange	7.8 *	27.6 xx	2.9
	Woodhouselee	0.9	8.2 x	4.1
Lying resting and ruminating (day)	Grange	6.3	52.1 xx	12.2 *
	Woodhouselee	8.1 *	63.8 xx	2.7
Camping	Grange	5.4	42.1 xx	28.2 **
	Woodhouselee	3.9	32.8 xx	33.1 **
Standing alert	Grange	2.8	6.1 *	19.2 **
	Woodhouselee	3.1	12.0 *	15.3 **
Scratching	Grange	17.2 xx	38.7 **	7.2 *
	Woodhouselee	11.1 xx	29.5 **	4.5

* denotes area where that activity occurred more often than expected given random use of areas, at $p<0.05$.

** denotes area where that activity occurred more often than expected given random use of areas, at $p<0.01$.

x denotes area where that activity occurred less often than expected given random use of areas, at $p<0.05$

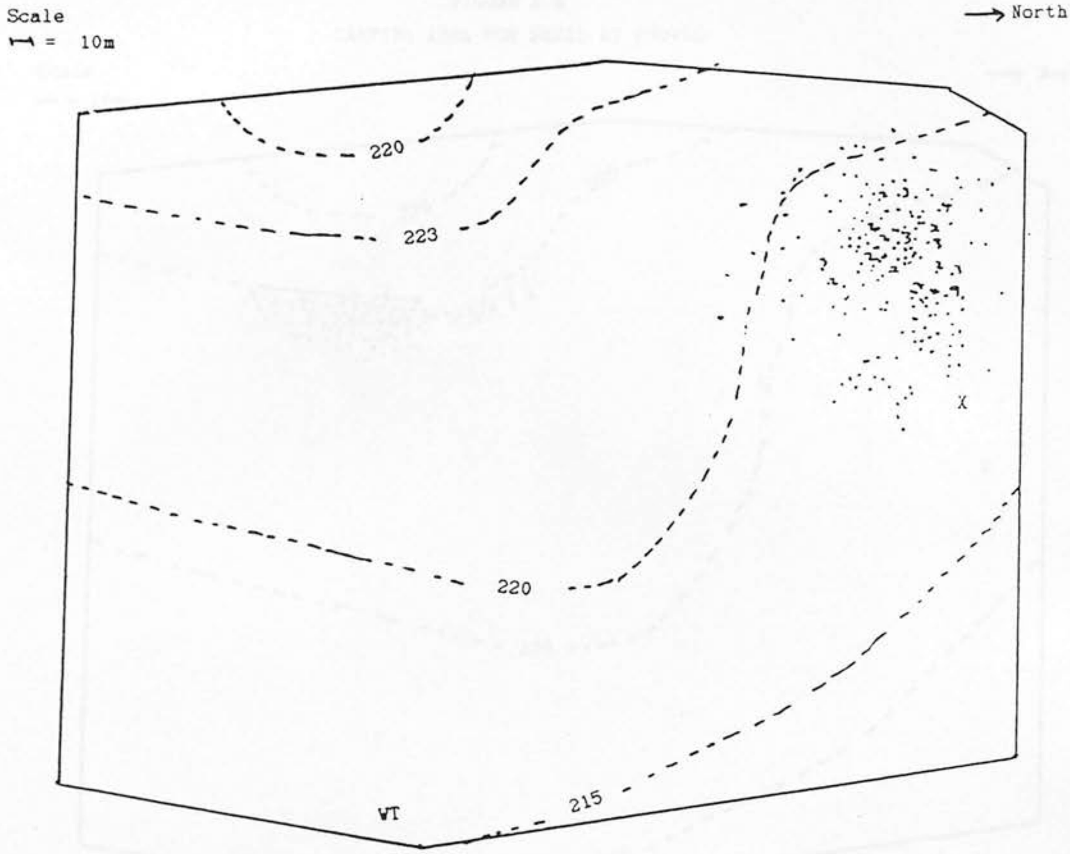
xx denotes area where that activity occurred less often than expected given random use of areas, at $p<0.01$.

degrees of freedom for Grange group was 4
degrees of freedom for Woodhouselee group was 2

could be due to predator avoidance or re-adjusting to the sudden change in light. The significant lack of grazing activity in the wooded areas would support the predator avoidance as the animals do appear very reluctant to spend time at all in such enclosed spaces. This may in part be due to the lack of palatable pasture in these areas. However, as the Grange sheep had an area of enclosed pasture (area B Figure 2.2) similar in pasture quality to that less enclosed (area A Figure 2.2) which was used significantly more for grazing than expected given their relative sizes, it would appear that the lack of a clear view is a deterrent to the use of an area. Areas A and B (Figure 2.2) also differ in that B is sloping and A is flat, but as in the Woodhouselee group no difference was seen in the use of the sloping or flat parts of open pasture (Area A/B Figure 2.3) for grazing, the most likely factor affecting the lack of grazing activity for the Grange sheep in area B (Figure 2.2) is the enclosed nature of this. The areas used predominantly for lying resting and ruminating during the day and camping at night are shown in Figures 2.7 - 2.12. Only the 20 individially marked sheep positions are given for the Knowes group. Open pasture was also distinctly favoured for lying resting and ruminating during the day by both groups, although the Grange sheep had a preference for one edge of this by a low hedge. The daytime lying areas were always close to the hayrack, and the effect of moving this is shown for the Grange sheep (Figure 2.9). In contrast to their daytime choice, the sheep lay to camp for the night by boundaries at the edge of open pasture, and particular spots were used very consistently. The camping areas were also characterised by

FIGURE 2.7

DAYTIME LIVING AREA FOR SHEEP AT KNOWES



Position of sheep ●

Integers represent positions where sheep were seen more than once

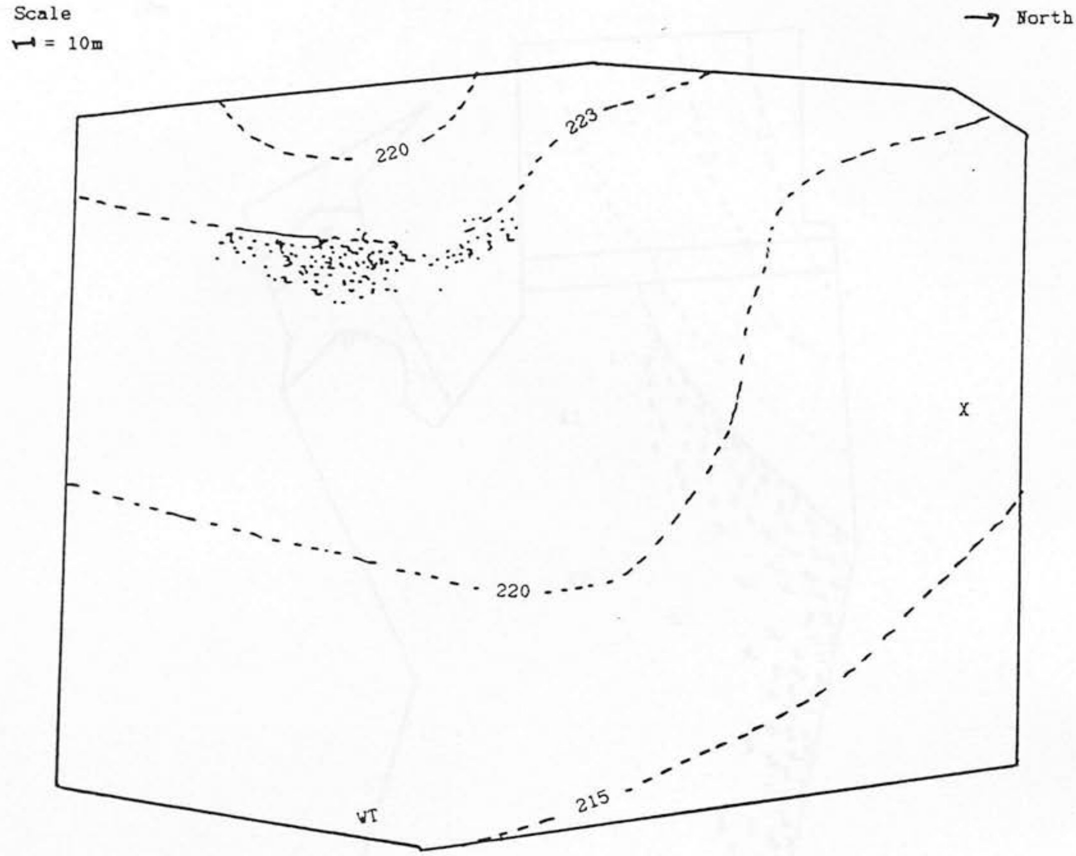
X Position of hay rack

WT Position of water source

---220--- Contour line

FIGURE 2.8

CAMPING AREA FOR SHEEP AT KNOWES



Position of sheep ●

Integers represent positions where sheep were seen more than once

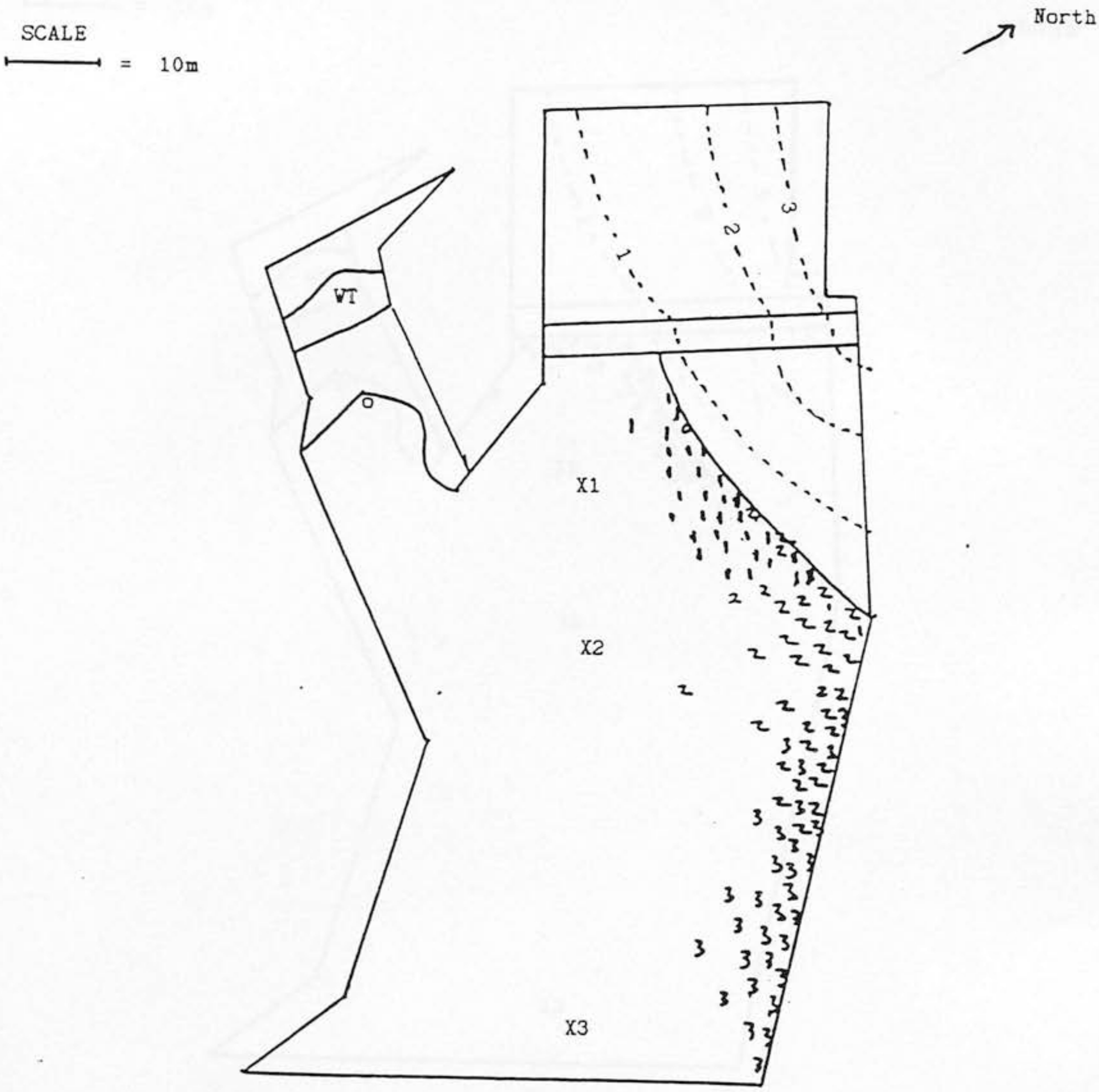
X Position of hay rack

VT Position of water source

---220--- Contour line

FIGURE 2.9

DAYTIME LYING AREA FOR SHEEP AT GRANGE



1 Position of sheep when hay rack was at X1

2 Position of sheep when hayrack was at X2

3 Position of sheep when hayrack was at X3

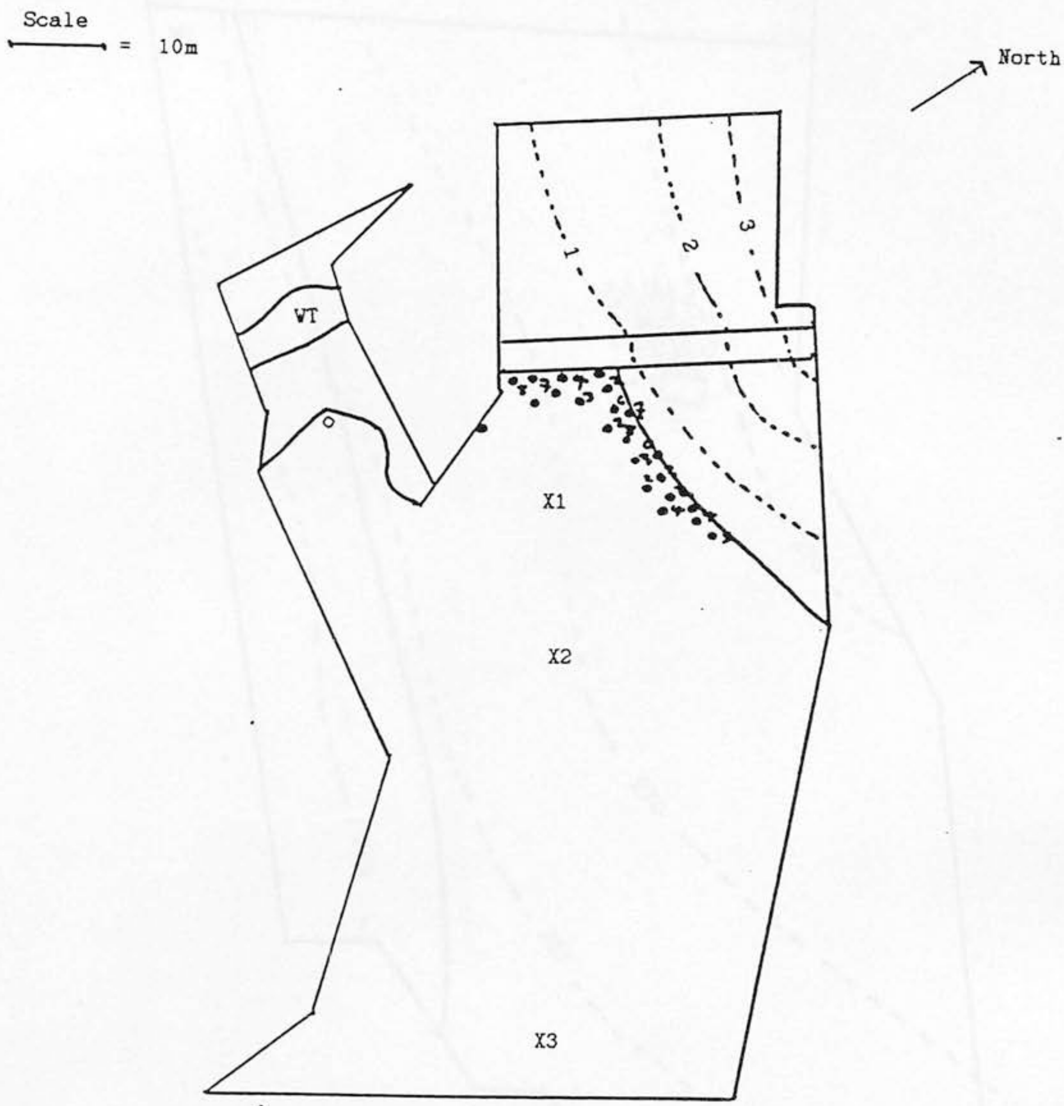
o Large tree

WT Water source

---1--- Contour line

Figure 2.10

CAMPING AREA FOR SHEEP AT GRANGE



Position of sheep

Integers represent positions where sheep were seen more than once

X1, X2, and X3 represent successive positions of hay rack

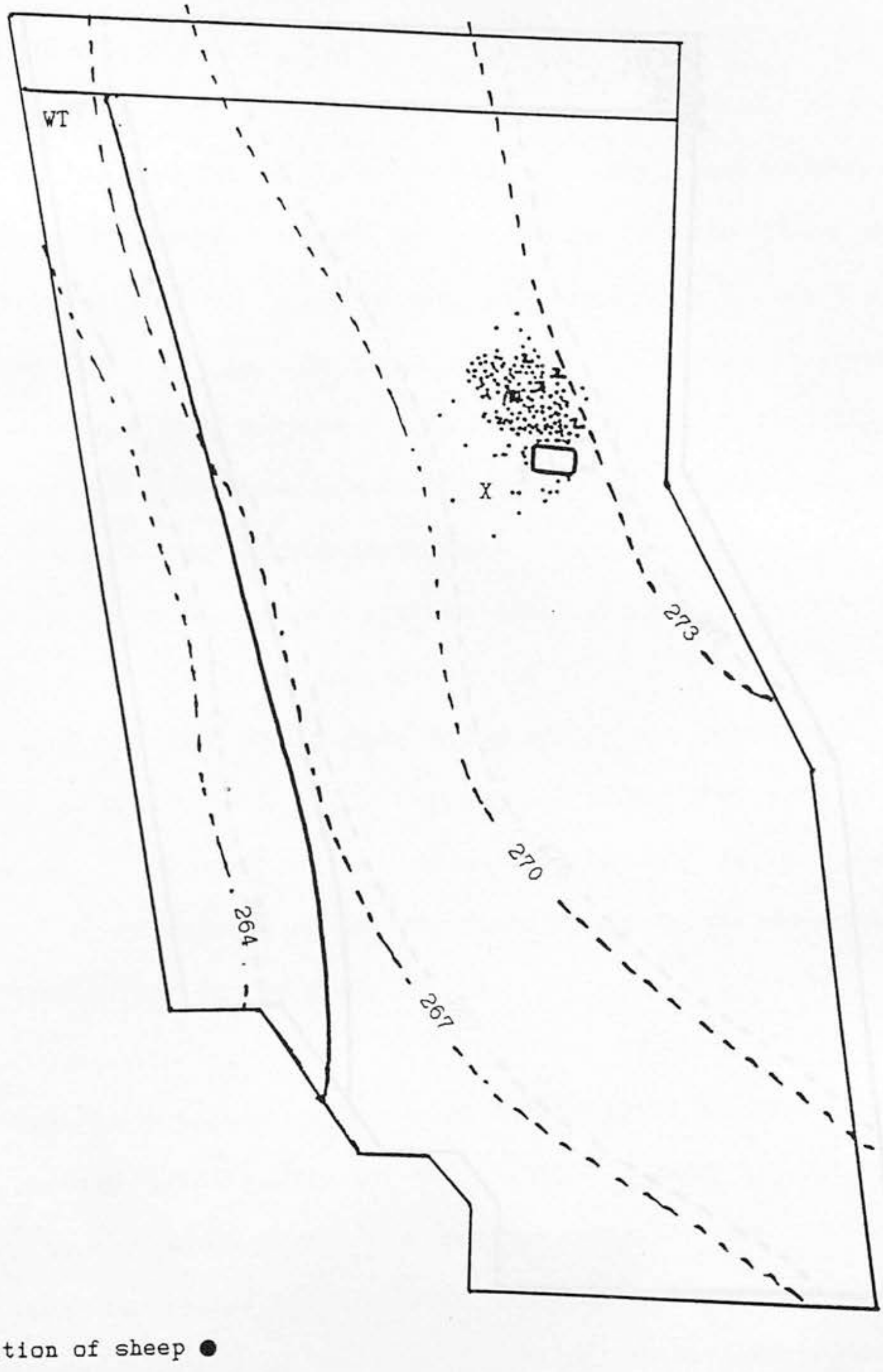
o Large tree

WT Water source

---1--- Contour line

FIGURE 2.11

DAYTIME LIVING AREA FOR SHEEP AT WOODHOUSELEE



Position of sheep ●

Integers represent positions where sheep were seen more than once

Position of haystack

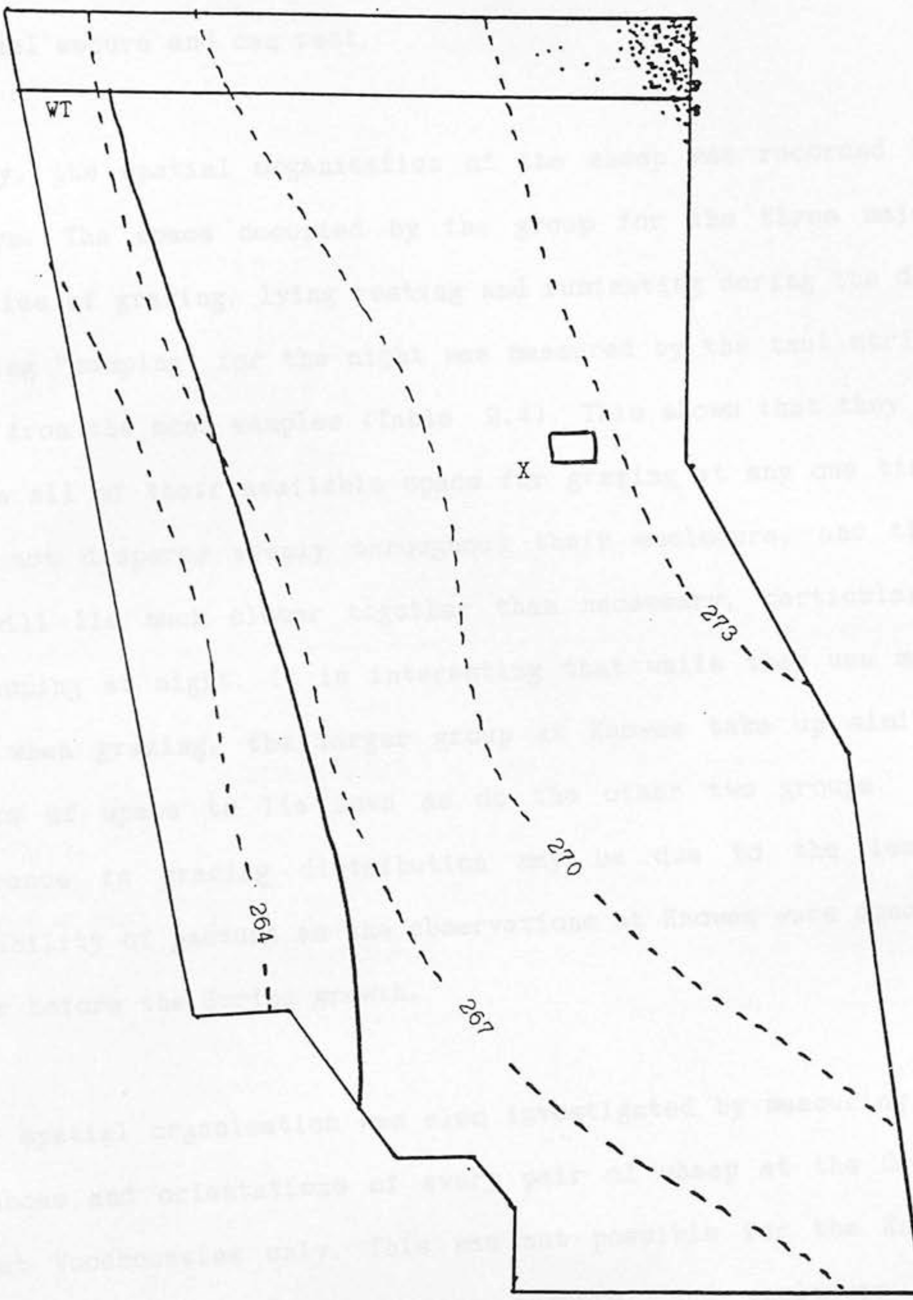
WT Water source

---270--- Contour line

Shed □

FIGURE 2.12

CAMPING AREA FOR SHEEP AT WOODHOUSELEE



Position of sheep ●

Integer represents positions where sheep were seen more than once

X Position of haystack

WT Position of water source

---200--- Contour line

being at the top of the available hill, suggesting again that a good wide open view is an important feature of the areas where the sheep feel secure and can rest.

Secondly, the spatial organisation of the sheep was recorded in two ways. The space occupied by the group for the three major activities of grazing, lying resting and ruminating during the day and lying "camping" for the night was measured by the taut string method from the scan samples (Table 2.4). This shows that they do not use all of their available space for grazing at any one time, ie do not disperse evenly throughout their enclosure, and that they will lie much closer together than necessary, particularly for camping at night. It is interesting that while they use more space when grazing, the larger group at Knowes take up similar amounts of space to lie down as do the other two groups. The difference in grazing distribution may be due to the lesser availability of pasture as the observations at Knowes were done in Winter before the Spring growth.

Their spatial organisation was also investigated by measuring the distances and orientations of every pair of sheep at the Grange and at Woodhouselee only. This was not possible for the Knowes sheep due to their much greater numbers, and enclosure size limiting the accuracy of the scan recording. Inter-sheep distances and the angle of orientation were measured as previously mentioned (Figure 2.4). The total amount of available data was sampled to collect one scan per hour at the same time of day over two days

TABLE 2.4

SPACE OCCUPIED BY SHEEP OUTDOORS IN VARIOUS ACTIVITIES

Activity	Space occupied (m^2/sheep)					
	Knowes		Grange		Woodhouselee	
	mean	(±SE)	mean	(±SE)	mean	(±SE)
Grazing	51	(±7.8)	22	(±5.3)	31	(±4.8)
Lying resting or ruminating (day)	12	(±1.0)	8	(±0.4)	9	(±0.6)
Camping (lying at night)	8	(±0.3)	7	(±0.4)	7	(±0.4)

for each group, in order to accommodate potential bias due to any effects of activity, time of day and weather.

This gave 14 scan samples per group and with a possible 28 combinations of all pairs per scan, resulted in a sample of 392 paired distance and orientation scores for each of these two groups. For both the Grange and the Woodhouselee groups, using Spearman's rank correlation test, no significant relationship between distance and orientation was found (r= 0.08 N=392 for the Grange and r=0.06 N=392 for those at Woodhouselee, both @ p=0.05).

However, as activity has a considerable effect on distance between animals and also affects one individual's perception of another, any relationship between distance apart and orientation may vary according to the activity of each animal. The three major activities involved were grazing, lying ruminating and lying resting. The data was therefore separated into the following classes for further analysis; pairs both lying, pairs both grazing and pairs with one grazing and one lying. The pairs both lying category was further subdivided into pairs both lying ruminating, pairs both lying resting and pairs with one lying resting and one lying ruminating.

Within these separate activity categories, no significant relationships between distance and angle of orientation were found, using Spearmans rank correlation tests (Table 2.5). This lack of relationship may have been due to the small sample size

TABLE 2.5

RELATIONSHIP BETWEEN DISTANCES AND ORIENTATION

FOR SHEEP IN VARIOUS ACTIVITIES

Activity of pair	Spearman's rank coefficient of correlation (rs)			
	Grange		Woodhouselee	
	rs	(n)	rs	(n)
Both grazing	0.06	(272)	0.05	(254)
One grazing, one not	0.12	(11)	0.29	(14)
Both lying ruminating	0.30	(32)	0.22	(41)
Both lying resting	0.16	(49)	0.17	(52)
One lying ruminating, one lying resting	0.08	(28)	0.17	(13)

n=sample size

from the subdivision of the data or again due to the masking of any local effects by the consideration of all distances together, as within each of these behavioural categories, the actual distance between animals may in itself change any relationship with orientation. For example, it could be supposed that there might be some distance beyond which the sheep no longer notice or respond to each other. Data including such figures would confound any relationship shown at closer distances, and the actual point at which the animals stop responding to each other would be a very useful guide to determining perceived "social space" or "group size". To look for such an effect, the data within each behavioural category were then further sorted, according to distance between sheep, divided into 5m series.

This further subdivision of the data did not show up any significant relationships between distance and orientation in any group or behavioural category (Table 2.9). In 2 cases out of the total 30 the significant figures obtained was most likely due to chance, as out of 20 tests done, 1 can be expected to show a significant effect at p=0.05. Also, with larger sample sizes, the probability of obtaining a spuriously high coefficient of correlation by chance is considerablty increased. However, as both these results were in the case of sheep grazing at modal distances, it may be that the apparently significant relationship found reflects the habit often commented on of sheep grazing in small groups tending to be orientated parallel to one and other.

TABLE 2.9

RELATIONSHIP BETWEEN DISTANCES AND ANGLE OF ORIENTATION OF SHEEP IN VARIOUS ACTIVITIES AND AT VARIOUS DISTANCES APART

Activity	Distance	Spearman's rank coefficient of correlation (rs)			
		Grange		Woodhouselee	
		rs	(n)	rs	(n)
Both grazing	≤5	0.39	(11)	0.29	(8)
	6-10	0.18	*(106)	0.11	(68)
	11-15	0.09	(83)	0.69	*(133)
	16-20	0.11	(42)	0.27	(29)
	>20	0.02	(30)	0.21	(16)
Both lying	≤5	0.28	(29)	0.31	(17)
	6-10	0.09	(43)	0.18	(52)
	11-15	0.21	(17)	0.26	(38)
	16-20	0.09	(12)	0.24	(10)
	>20	0.12	(8)	0.22	(7)
One lying, other grazing	≤5	NA	(1)	NA	(1)
	6-10	NA	(1)	NA	(1)
	11-15	0.20	(5)	0.33	(6)
	16-20	0.14	(3)	0.21	(4)
	>20	NA	(1)	0.02	(2)

n = sample size

* denotes a significant correlation at $p<0.05$

NA means not applicable, as cannot do calculation at n=1

In order to make some comparisons with the data from later indoor experiments, the mean and modal distances and orientations were calculated for each group for the main behavioural categories (Tables 2.6 - 2.8 and 2.10 - 2.12). These figures show the same pattern of distribution as the space taken up per head already given in Table 2.4. As there was considerable variation in the data measured, the modal distances were included as representing actual distribution more accurately.

Social interactions were recorded from the focal animal samples. Almost all of their interactions can be said to be affiliative, as in all three groups the sheep stayed closer than they had to with the only obvious aggressive interactions occurring over the supplementary feed. These consisted mainly of pushing each other out of the way. The displaced animal immediately found another place at the trough and the interactions were not sufficient in number to make any measure of social hierarchy in any group.

TABLE 2.6

MEAN AND MODAL DISTANCES BETWEEN

SHEEP IN VARIOUS ACTIVITIES

Activity	Nearest neighbour distance (metres)					
	Grange (n=8)			Woodhouselee (n=8)		
	mean	(±SE)	mode	mean	(±SE)	mode
Grazing	4.8	(±1.9)	5.3	7.5	(±1.2)	7.9
Lying (day) resting or ruminating	3.0	(±1.2)	2.1	4.1	(±0.9)	3.9
Lying (night) camping	1.1	(±0.4)	0.9	0.9	(±0.3)	1.2

TABLE 2.7

MEAN AND MODAL DISTANCES BETWEEN SHEEP IN VARIOUS ACTIVITIES.

Activity	Distance to farthest sheep (metres)					
	Grange (n=8)			Woodhouselee (n=8)		
	mean	(±SE)	mode	mean	(±SE)	mode
Grazing	17.1	(±4.1)	13.0	20.2	(±3.2)	17.3
Lying (day) resting or ruminating	7.2	(±1.9)	5.1	8.3	(±0.8)	7.8
Lying (night) camping	5.1	(±0.7)	5.3	5.3	(±1.1)	6.3

TABLE 2.8

Mean and modal distances between sheep in various activities.

Activity	Distance between all sheep (metres)					
	Grange (n=8)			Woodhouselee (n=8)		
	mean	(±SE)	mode	mean	(±SE)	mode
Grazing	9.2	(±3.1)	10.2	11.2	(±2.0)	12.2
Lying (day) resting or ruminating	5.9	(±1.3)	2.9	6.2	(±0.5)	7.1
Lying (night) camping	3.2	(±0.3)	1.8	3.9	(±0.7)	2.5

TABLE 2.10

MEAN AND MODAL ANGLE OF ORIENTATION BETWEEN SHEEP IN VARIOUS ACTIVITIES

Activity	Angle of orientation to nearest neighbour (degrees)					
	Grange (n=8)			Woodhouselee (n=8)		
	mean	(±SE)	modal range	mean	(±SE)	modal range
Grazing	12	(±3.9)	0-9	14	(±3.5)	10-19
Lying (day) resting or ruminating	105	(±5.2)	90-99	100	(±4.1)	90-99
Lying (night) camping	123	(±9.1)	80-89	119	(±3.3)	80-89

TABLE 2.11

MEAN AND MODAL ANGLE OF ORIENTATION

BETWEEN SHEEP IN VARIOUS ACTIVITIES

Activity	Angle of orientation to farthest sheep (degrees)					
	Grange (n=8)			Woodhouselee (n=8)		
	mean	(±SE)	modal range	mean	(±SE)	modal range
Grazing	44	(±4.2)	20-29	39	(±3.4)	20-29
Lying (day) resting or ruminating	107	(±6.2)	90-99	102	(±4.8)	100-109
Lying (night) camping	116	(±3.7)	100-109	112	(±4.2)	100-109

TABLE 2.12

MEAN AND MODAL ANGLE OF ORIENTATION

BETWEEN SHEEP IN VARIOUS ACTIVITIES

Activity	Angle of orientation to all sheep (degrees)					
	Grange (n=8)			Woodhouselee (n=8)		
	mean	(±SE)	modal range	mean	(±SE)	modal range
Grazing	23	(±2.8)	10-19	20	(±2.5)	11-20
Lying (day) resting or ruminating	106	(±4.1)	90-99	101	(±3.7)	100-109
Lying (night) camping	120	(±3.1)	100-109	118	(±2.9)	110-119

CONCLUDING POINTS

1. The sheep spend most of the daylight hours alternating grazing with lying resting and ruminating. There were two main bouts of grazing with a third occasionally in between later in the season. The last bout finished at dusk. Enclosed areas of pasture were used less than the more open areas, and no distinction was found between sloping and flat areas.

2. The sheep were not evenly dispersed over their enclosure, remaining as a cohesive social group, using the areas available in a non uniform way. Areas used for lying resting and ruminating during the day were characterised by open pasture and proximity to the hayrack. Areas used for camping at night were characterised by proximity to boundaries and height, offering a wide view.

3. There was considerable allelomimicry and lack of overt aggression seen in their daily activities.

HOUSED SHEEP IN INTENSIVE CONDITIONS

AIM

The aim of this set of observations was to examine the behaviour of sheep housed in conditions typical of those found in over-wintered sheep, to compare with those housed extensively, to see if there were any changes indicating a decrease in welfare and to discover which environmental features were associated with this.

MATERIALS AND METHODS

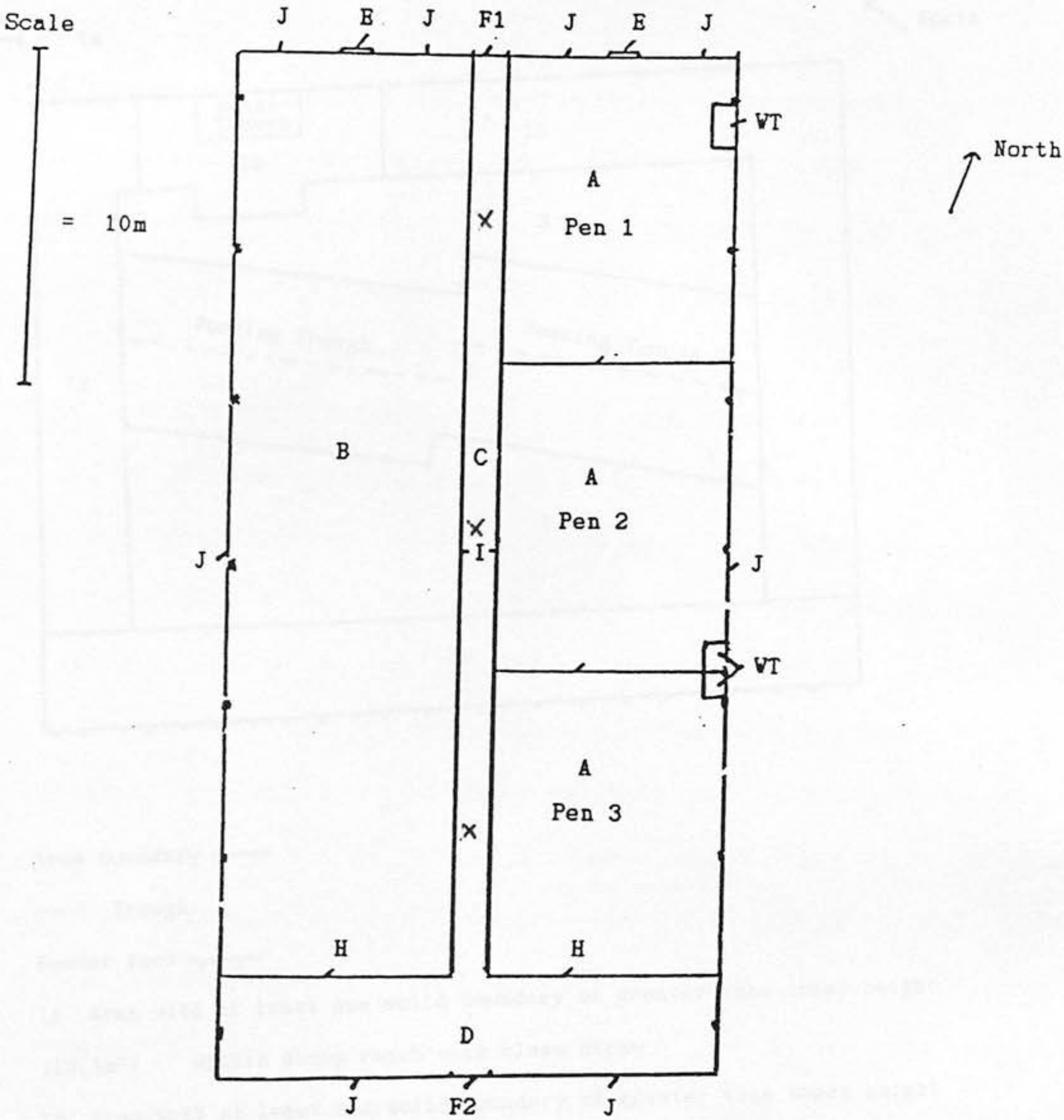
Five different groups of 30 sheep were studied. All animals were housed in the same shed at Glencorse. Three of these (Groups 1, 2 and 3) were housed in adjacent pens at the same time in 1985, Group 4 were housed in one of these pens in the next year, 1986 and Group 5 were housed in this same pen in the following year, 1987.

Details of the animals, shed and management methods were as given in the General Materials and Methods Section.

A scale diagram of the shed is given in Figure 3.1. All pens were identical except for the water trough position. Each pen measured 9 x 7 metres, giving 2.1 m^2/sheep. A diagram showing the variety of environmental features within the pens is given in Figure 3.2. along with the dimensions of each of these areas. 1m was taken as the maximum distance for which a boundary was considered to be

FIGURE 3.1

SCALE DIAGRAM OF SHED AND PENS AT GLENCORSE



A Pens used for indoor observations (each $63m^2$)

B Identical pens of sheep or cattle on other experiments

C Area of central passageway, with X showing observation points

D Storage area at end of shed

E Door, often blocked by gate

F1 Door kept open

F2 Door kept closed

G Pen divisions

H Brick partition wall in shed

I Feeder face

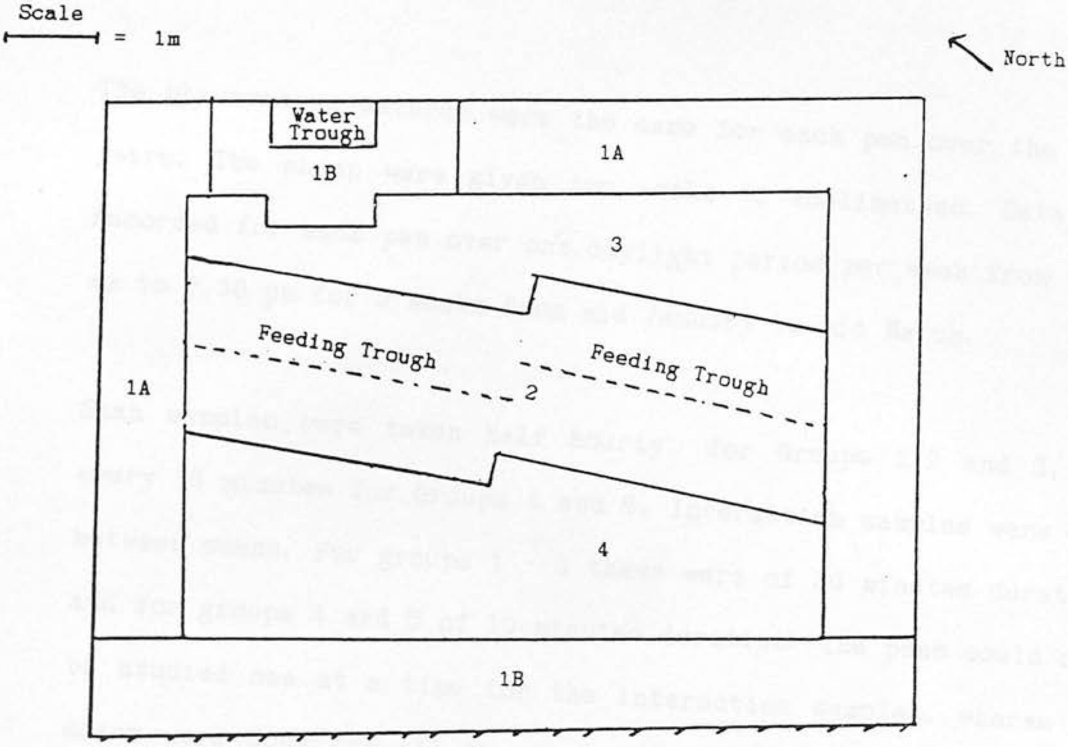
J Outer walls of shed

WT Water source

Post

FIGURE 3.2

SCALE DIAGRAM OF PEN AT GLENCORSE TO SHOW DIFFERENT AREAS WITHIN PEN



Area boundary ——

---- Trough

Feeder face

1A Area with at least one solid boundary of greater than sheep height
(13.4m²) within sheep reach with clean straw

1B Area with at least one solid boundary of greater than sheep height
(10.5m²) within sheep reach with dirty, trampled straw

2 Area with a solid boundary of less than sheep height within sheep
(14.5m²) reach with clean straw

3 Area with no solid boundaries within sheep reach and relatively
(10.0 m²) clean straw

4 Area with no solid boundaries within sheep reach and well trampled
(14.5 m²) straw

within sheep reach, as 1m is the approximate length of these sheep.

The observation methods were the same for each pen over the three years. The sheep were given two weeks to acclimatise. Data were recorded for each pen over one daylight period per week from 10.30 am to 3.30 pm for 9 weeks from mid January to mid March.

Scan samples were taken half hourly for Groups 1,2 and 3, and every 15 minutes for Groups 4 and 5. Interaction samples were done between scans. For groups 1 - 3 these were of 20 minutes duration, and for groups 4 and 5 of 10 minutes duration. The pens could only be studied one at a time for the interaction samples, wheras the scans were done for all three pens in year one (groups 1-3) at the same time and for one other modified pen along with each of groups 4 and 5 (see later for details of this part of the experimental section). This meant that for groups 1-3 the interaction samples for each pen were done after every third scan sample for that pen, and for groups 4 and 5 the interaction samples were done after every other scan sample for each pen. In addition, 20 minute focal animal studies were done on a sample of 8 sheep from each group on different days of the same 9 week period to give 3 per individual spread evenly (one in each 2 hour section) over the day (from 10.30am to 3.30pm).

The space occupied by the group, distances between sheep and their orientation to each other were all measured as for the previous section, as described in the General Materials and Methods Section.

The weather was recorded as previously (for the Outdoor Sheep in Extensive Enclosures), except that in this experiment the temperature measured was that inside the shed.

RESULTS AND DISCUSSION

The ethogram developed for these indoor sheep is given in Appendix B.

The time budgets calculated from the scan samples are given in Table 3.1. As the number of scans obtained for each group varied between the groups, the data are represented as percentages (of total time observed per day) in Table 3.2. There were no significant differences found between groups 1, 2 and 3, suggesting that, as expected the three pens within the shed do not afford substantially different environments. Also, no significant differences were seen between groups 4 and 5 done in different years. Although these differences are not statistically significant, there is quite a lot of variation when the means are expressed as percentages (Table 3.2). This is because the lack of significant differences was due not so much to similarity in the

TABLE 3.1

TIME BUDGETS OF INDOOR SHEEP;

TIME SPENT IN PARTICULAR ACTIVITIES

Activity	Number of scans									
	Group 1		Group 2		Group 3		Group 4		Group 5	
	mean	(±SE)	mean	(±SE)	mean	(±SE)	mean	(±SE)	mean	(±SE)
Feeding (F)	42	(±3.1)	48	(±3.2)	52	(±4.0)	92	(±4.1)	89	(±3.9)
Lying ruminating (LM)	19	(±2.1)	9	(±6.9)	8	(±3.0)	20	(±3.1)	26	(±2.1)
Lying alert (LA)	18	(±3.2)	16	(±1.5)	14	(±2.1)	28	(±2.1)	24	(±2.9)
Lying alert ruminating (LMA)	6	(±1.1)	5	(±1.2)	4	(±1.3)	11	(±1.9)	14	(±1.9)
Lying resting (LR)	8	(±0.4)	7	(±1.1)	5	(±1.1)	12	(±2.3)	9	(±1.2)
Standing resting (SR)	3	(±0.3)	1	(±0.6)	1	(±0.9)	2	(±1.0)	2	(±0.9)
Standing ruminating (SM)	7	(±2.1)	9	(±3.1)	6	(±2.8)	12	(±1.9)	14	(±1.9)
Standing alert (SA)	12	(±1.1)	14	(±2.9)	9	(±2.1)	20	(±2.3)	17	(±1.1)
Standing alert ruminting (SMA)	4	(±1.1)	6	(±2.1)	1	(±0.5)	1	(±0.3)	2	(±0.5)
Other (O)	3	(±0.6)	1	(±0.2)	1	(±0.6)	1	(±0.4)	1	(±0.2)

Notes: 1. Group size = 30 in all groups.

2. The total number of scans varies: for groups 1-3 this is 99, and for groups 4-5 this is 198, in both cases representing 21% of 24 hours.

TABLE 3.2

TIME BUDGETS OF INDOOR SHEEP;

TIME SPENT IN COMBINED ACTIVITY CATEGORIES (%)

Activity	Group 1	Group 2	Group 3	Group 4	Group 5
Feeding (F)	42	48	52	44	39
Ruminating (LM+LMA+SM+SMA)	28	24	29	30	23
Resting (LR+SR)	11	4	7	6	8
Lying (LM+LMA+LR)	40	31	29	35	32
Standing (SR+SM+SA+SMA)	26	22	23	19	17
Alert (LMA+SA+SMA)	40	35	31	29	37

Figures for the means, but more to the large standard errors calculated for the means, an effect of the relatively high individual variation in time budgeting. From Table 3.2. it can be seen that the sheep spend just under half of their day feeding, some two thirds of the remaining time lying, and one third of this standing. Around 5% of their time is spent resting, with approximately one quarter of their time ruminating. In contrast to the 5% of their time spent resting, around one third of their time is spent alert. It should also be remembered that the sheep are also alert and standing while feeding.

The relatively high amounts of time standing are most likely to be due to the lack of space to lie, with an average spacing of $2m^2$ per sheep. Animals moving to and from the feeder face disturb those lying in the centre of the pen, which are often forced to get up out of the way. The high levels of alertness could be due in part to the relatively small group size. It could also be due to the close proximity of other sheep, and the subsequent high levels of aggression, the sheep needing to look out for others competing for space. It could also be an attempt to improve predator surveillance in an enclosed space. In animals used to a relatively expansive view, such persistent increase in alertness may be indicative of lowered threshold of stimulation for visual feedback from a dull environment. For this reason and as early detection and consequent avoidance of approaching predators is the major way of dealing with these by sheep, these high levels of alertness may be indicative of a lack of welfare.

The pattern of feeding and lying resting or ruminating throughout the day is illustrated in Figures 3.3 and 3.4 respectively. There are generally some sheep feeding and some lying resting or ruminating at most times, although there are periods in which most of the sheep are feeding and in which most are lying. Generally there is little allelomomicry or daily routine seen (Figures 3.3 and 3.4); the animals having lots of short bouts of feeding alternating with lying resting and ruminating throughout the part of the day which was observed.

The areas within the pen (Figure 3.2) were not used uniformly (chi^2=17.5). Certain activities occurred predominantly in certain areas of the pen, as shown in Table 3.3. In particular, the sheep were found lying resting more often around the edges of the pen than expected from a random regular distribution throughout the pen, and lying generally more in the back rather than the front of the pen. They were also found standing and alert more often in the centre and towards the front of the pen. This distribution suggests that areas characterised by solid barriers within sheep reach and possibly also less disturbance and cleaner straw are more conducive to resting behaviour. As the sheep could only feed from the feeding face, this activity was not included in the overall analysis of area use as this would have considerably biased the results.

There were a great many aggressive interactions seen. Table 3.4 shows the mean numbers of aggressive interactions along with the mean numbers of threats and butts involved per interaction for

FIGURE 3.3

PATTERN OF FEEDING BEHAVIOUR OF INDOOR SHEEP

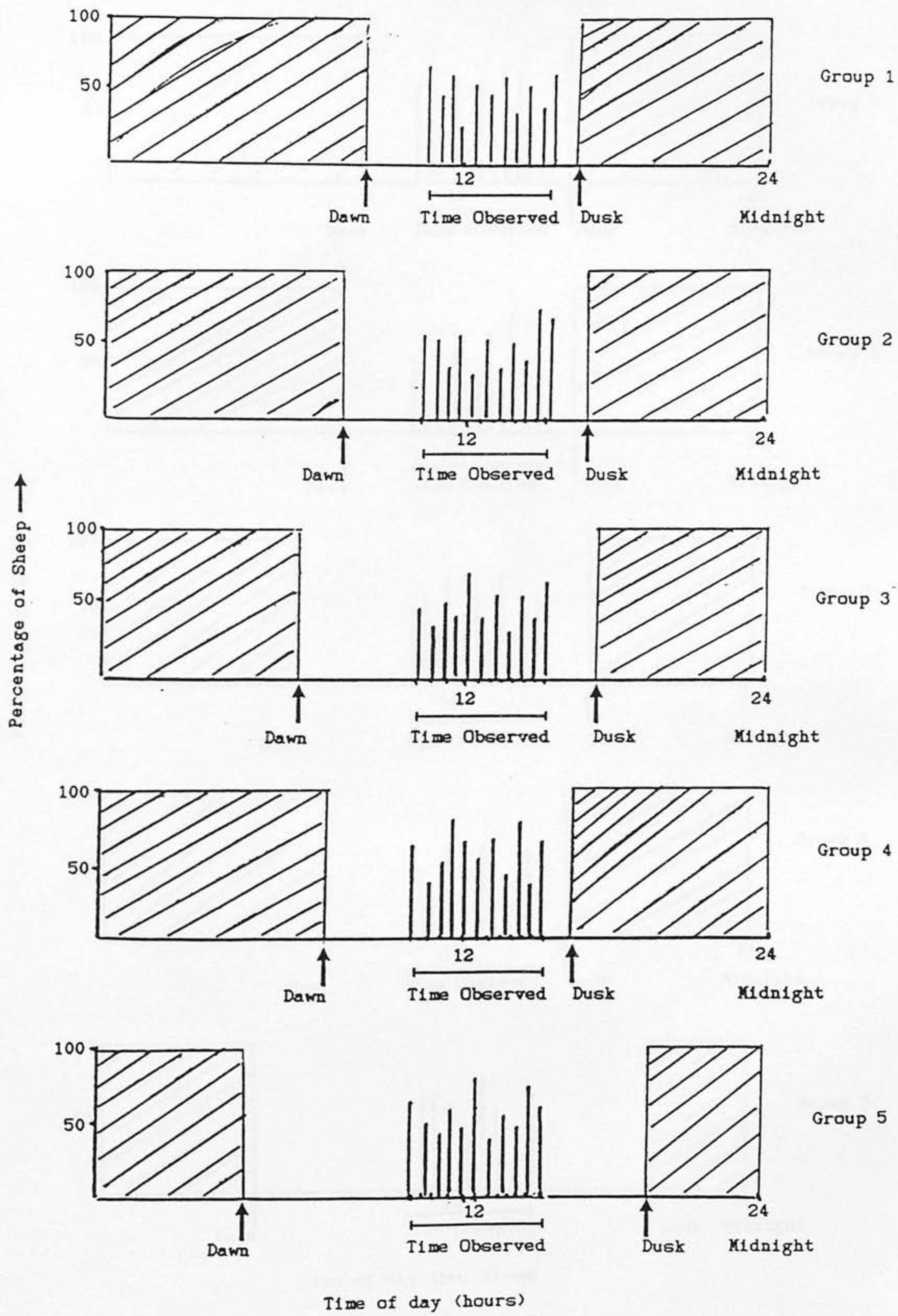


FIGURE 3.4

PATTERN OF LYING BEHAVIOUR OF INDOOR SHEEP

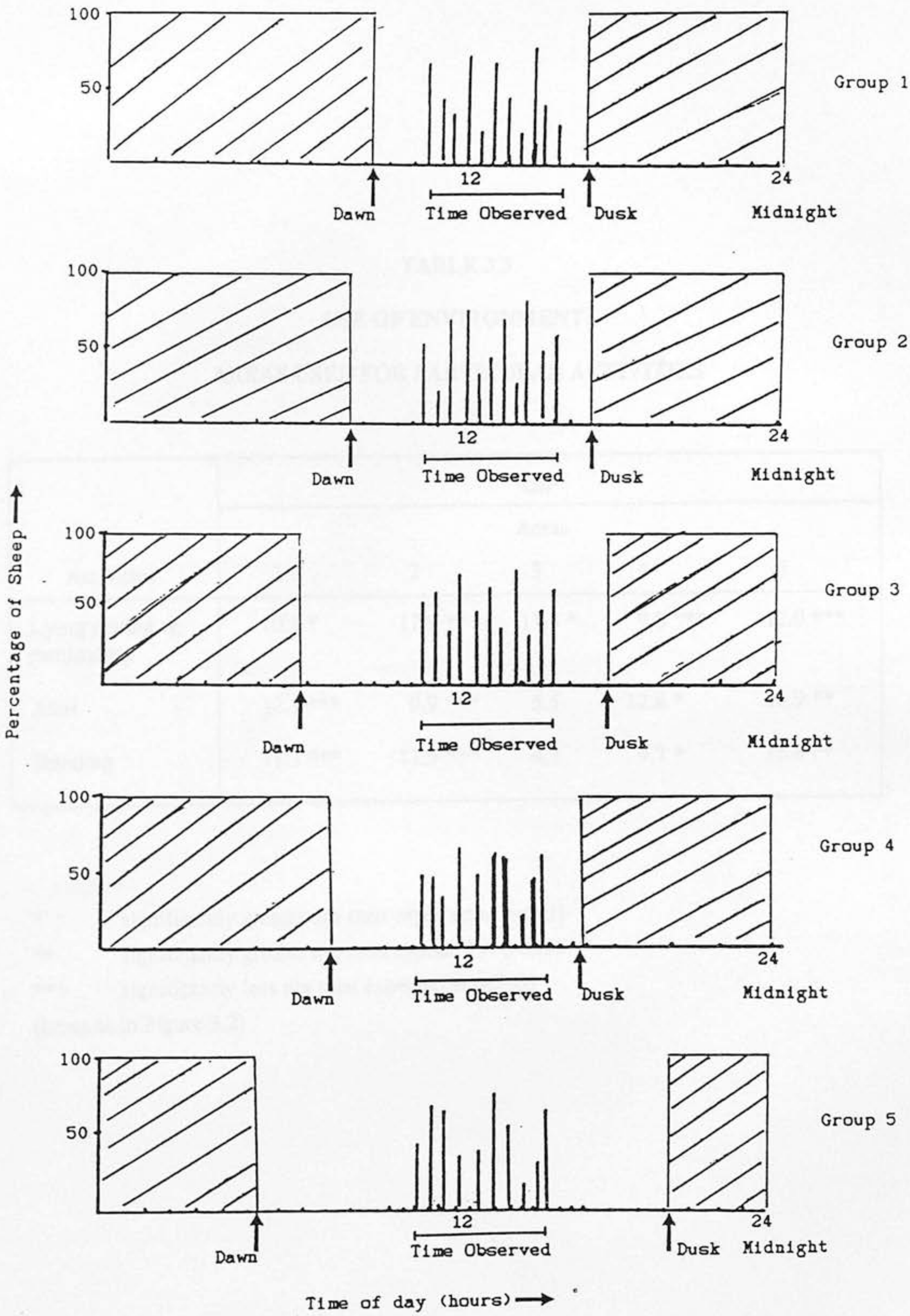


TABLE 3.3

USE OF ENVIRONMENT:

AREAS USED FOR PARTICULAR ACTIVITIES

	chi²				
	Areas				
Activities	1	2	3	4	5
Lying resting or ruminating	10.3 *	17.9 **	11.3 *	9.8 ***	12.0 ***
Alert	12.1 ***	9.9 ***	5.5	12.8 *	16.9 **
Standing	11.3 ***	11.9 ***	4.3	9.7 *	15.8 **

* significantly greater use then expected at $p<0.01$

** significantly greater use then expected at $p<0.05$

*** significantly less use then expected at $p<0.05$

(areas as in Figure 3.2)

TABLE 3.4

FREQUENCY OF AGGRESSIVE INTERACTIONS

Activity scored	Mean number per sheep per hour (±SE)				
	Group 1	Group 2	Group 3	Group 4	Group 5
Number of interactions	1.8 (±0.51)	1.7 (±0.32)	1.5 (±0.41)	1.2 (±0.43)	1.4 (±0.36)
Number of threats	2.6 (±0.51)	1.9 (±0.32)	2.1 (±0.29)	2.3 (±0.41)	2.7 (±0.42)
Number of butts	1.7 (±0.36)	1.5 (±0.29)	1.0 (±0.37)	1.2 (±0.40)	1.4 (±0.29)

each of the five groups of sheep. There was no significant difference (at $p<0.05$) between these and on average overall the mean number of interactions seen was 1.2 per sheep per hour, involving on average 1.3 butts and 2.6 threats. Almost all of these interactions involved displacement of one animal by another (93%) and in most cases the animal initiating the interaction 'won' by successfully displacing the recipient (99%). Most of these aggressive interactions could be directly attributed to competition over a particular resource as shown in Table 3.5. Approximately half of these are concerned with space at the feeder face and one third with lying space. Hence feeding space followed by lying space appear to be the most valued and/or restricted resources.

Certain individuals appeared to predominately win such aggressive competitive interactions, and a measure was made of the competitive ability of each animal. A score was calculated to represent this competitive ability (CA) for each individual by taking the number of interactions won divided by the total number of interactions in which the animal was seen. It was also noticed that certain individuals were often seen lying in a very specific site. These sites were considered to be within a one metre square area. This positional patterning (PP) was measured for each individual by calculating the number of times it was seen lying in that site and dividing by the number of times it was seen lying. There was a significant correlation between the CA and PP score for each individual (Spearman's rank coefficient of correlation $r_s = 0.39$ $N=150$). This suggests that the positional patterning was

TABLE 3.5

PERCENTAGE OF INTERACTIONS ATTRIBUTABLE

TO EACH RESOURCE

Resource	% Number of interactions
Feeding space	53
Lying space	32
Access	11
Water	<1
Unknown	4

(Figures combined for all five groups as mean numbers (Table 3.4) showed no differences) a positive choice indicating a preference for these sites by the more successfully competitive sheep. The sites used by the most successful sheep (those which won significantly more interactions than they lost, using chi^2testing with a random expectation of number lost equalling number won out of the total number of interactions in which an individual was seen) were characterised by being at pen edges, usually at the back of the pen (in 90% of the cases) and associated with a corner either of the pen sides or areas where the trough or roof supporting posts jutted out into the pen (in 75% of the cases).

Consideration of these results taken together ie. showing the animals non uniform use of the pen, the resources competed for and the positional preference tendency of successfully competitive sheep (over all resources) leads to the suggestion that that some feature of the pen edges and corners in particular is especially valued by the sheep and may be associated with the facility to lie and rest undisturbed. It is perhaps surprising that it is the successfully competitive animals which prefer these quiet 'out of the way' areas. Most of the aggressive interactions are won by the instigating animal, which almost always displaces the recipient from the resource over which they are competing. This means that it is these successful sheep which initiate and win most interactions over all resources and which are generally avoided by the other animals when they are in all other parts of the pen. They could therefore lie relatively undisturbed anywhere. It would be more understandable in terms of wishing to avoid aggressive encounters for the less successful sheep to choose the generally less disturbed areas. The preference for these areas by the successful sheep, apart from showing that some feature of these areas may be an especially valued resource as already mentioned, may also be in part due to a desire to avoid aggressive encounters themselves, even if they do generally initiate and win these. Hence there may be some 'cost' to the aggressor as well as to the agressed animal involved in such interactions, suggesting that the high levels of these aggressive interactions found may indicate a decrease the welfare status of all of the animals involved, not only those which lose.

The mean area used by the sheep did not vary significantly between groups nor was this significantly different from the total area available to them (Table 3.6). The mean distances between and orientations of the sheep were measured between all pairs as in the previous section for the outdoor sheep (Figure 2.4). The mean distances between sheep were not significantly between groups, and were all approximately around 1.5 metres (Table 3.7). This is very close when it is remembered that approximately 0.5m of this is taken up by the actual body width of the sheep. There was no significant variation with activity seen between instances in which both animals were lying or both were feeding. For those instances in which one was lying and one feeding, these distances were increased as the sheep could only feed at the front of the pen, and preferred to lie around the edges and towards the back. Orientation did not vary significantly between groups, but did vary with activity (Table 3.8). Lying animals were most often found at around right angles and feeding animals parallel. The

TABLE 3.6

AREA OCCUPIED BY GROUP

Area m^2/head	Group 1	Group 2	Group 3	Group 4	Group 5
Mean ($\pm$SE)	1.9 ($\pm$0.31)	1.7 ($\pm$0.29)	1.7 ($\pm$0.32)	1.8 ($\pm$0.41)	1.8 ($\pm$0.36)

TABLE 3.7

DISTANCES BETWEEN SHEEP

	Mean distances in metres (±SE)				
	Group				
Activity	1	2	3	4	5
Both feeding	0.9 (±0.21)	0.8 (±0.30)	1.1 (±0.21)	1.3 (±0.23)	0.9 (±0.29)
Both lying	1.3 (±0.21)	1.4 (±0.29)	1.1 (±0.31)	0.9 (±0.28)	1.0 (±0.25)
One feeding, other lying	3.2 (±0.31)	3.4 (±0.41)	2.8 (±0.42)	3.5 (±0.39)	3.7 (±0.32)

TABLE 3.8

ORIENTATION OF SHEEP

Activity	Angle of orientation: mean (±SE) [modal range] Group 1	2	3	4	5
Both feeding	9 (±3.1) [0-9]	12 (±2.9) [10-19]	21 (±4.0) [20-29]	15 (±3.9) [10-19]	17 (±5.3) [10-19]
Both lying	80 (±6.3) [80-89]	95 (±7.1) [90-99]	99 (±8.2) [90-99]	85 (±9.1) [80-89]	112 (±7.1) [110-119]
One feeding, other lying	70 (±9.1) [70-79]	92 (±7.8) [90-99]	113 (±8.2) [110-119]	78 (±9.1) [70-79]	129 (±7.2) [120-129]

mean figures for lying sheep are generally less than 90 degrees due to their preference for lying along and parallel to the pen edges.

There was no significant correlation found between distance and orientation calculated over all sheep; neither was any found when feeding and lying activities were considered separately (Table 3.9).

TABLE 3.9

CORRELATION BETWEEN DISTANCE
AND ORIENTATION OF SHEEP

Activity	Spearman's rank coefficient of correlation r				
	Group 1	Group 2	Group 3	Group 4	Group 5
Both feeding	0.19	0.02	0.08	0.03	0.05
Both lying	0.11	0.10	0.07	0.01	0.04
One feeding, other lying	0.02	0.01	0.01	0.04	0.02

CONCLUDING POINTS

1. An ethogram was developed for housed sheep.

2. Time budgets were drawn up for housed sheep. Little allelomimicry or pattern was seen in the daily bouts of feeding and lying resting or ruminating.

3. Much aggressive competition was seen, particularly over the resources of space to lie and feed.

4. Pen use was not uniform, the animals in particular preferring to lie along the pen edges and corners.

5. Measurement of the area occupied by and distances between animals showed that they made use of all of their available space, being as widely distributed as possible.

6. No consistent relationship was found between the distance and orientation of the sheep.

It is concluded that the levels of alertness and aggressive competition seen could contribute to a lack of welfare in housed sheep, and that these appear to be associated with lack of specific resources within the pen, especially for space to feed and to lie, particularly along pen edges and corners.

MODIFIED PENS - BARRIER CHOICE TRIAL

AIM

The aim of this trial was to determine which features of the pen edges are involved in the animals' preference for these areas in which to lie.

MATERIALS AND METHODS

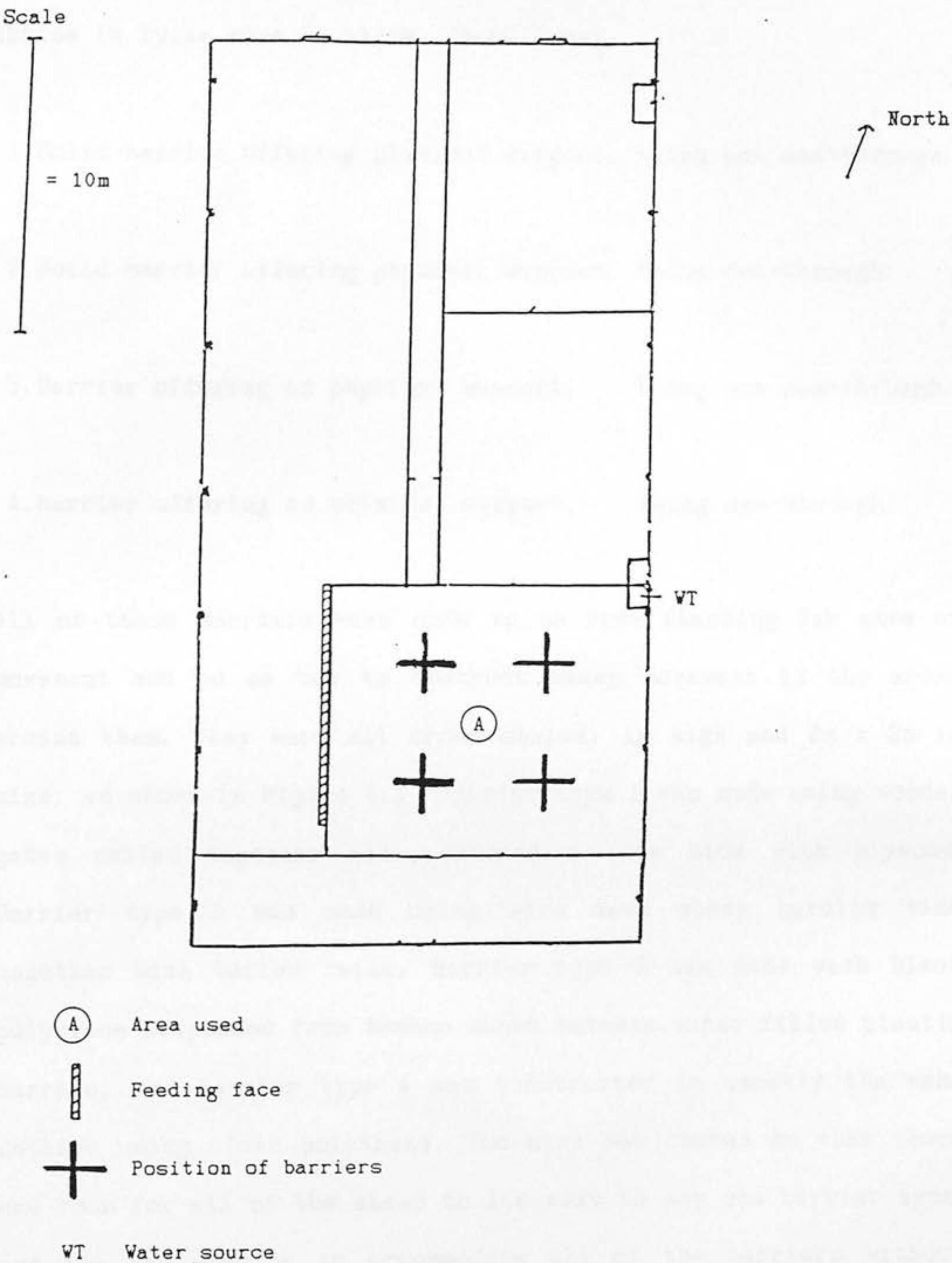
A group of 8 sheep were studied for an 18 day period during December 1985 and January 1986, housed in the same shed at Glencorse as was used for the 'Indoor Sheep in Typical Housing' set of observations as described in the previous section.

Details of animals, shed and husbandry methods were as described in the General Materials and Methods Section.

The area of the shed in which the animals were penned is shown in Figure 4.1. This gave $12m^2$ of space per sheep and the sheep were fed along an 8m strip as shown.

FIGURE 4.1

PEN USED FOR BARRIER CHOICE TRIAL WITHIN SHED AT GLENCORSE



Four different barriers were used in order to isolate various features of the pen edges which may contribute to the animals' choice in lying next to these. These were;

1. Solid barrier offering physical support, being non see-through.

2. Solid barrier offering physical support, being see-through.

3. Barrier offering no physical support, being non see-through.

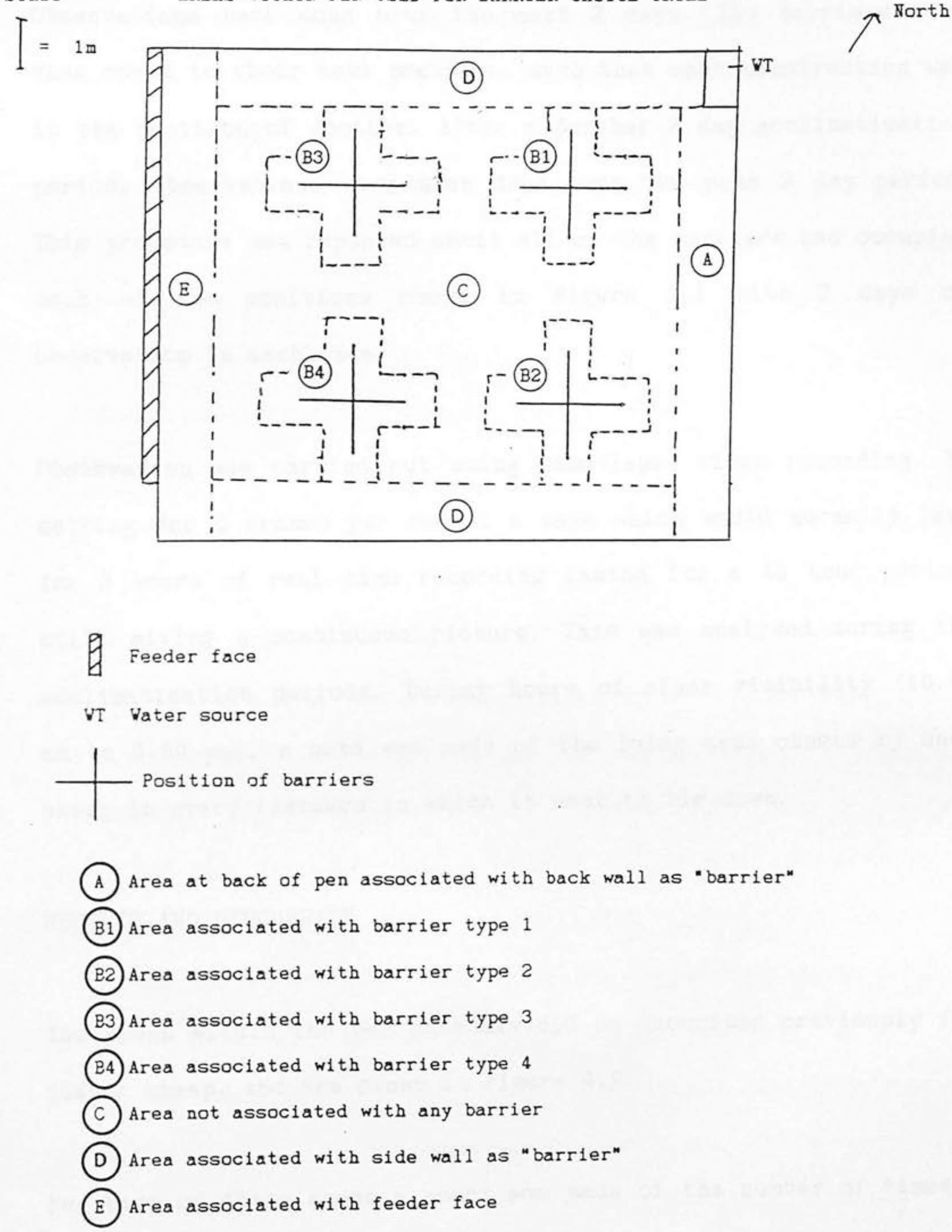
4. Barrier offering no physical support, being see-through.

All of these barriers were made to be free standing for ease of movement and so as not to obstruct sheep movement in the areas around them. They were all cross shaped, 1m high and 2m x 2m in size, as shown in Figure 4.1. Barrier type 1 was made using wooden gates nailed together and covered on one side with plywood. Barrier type 2 was made using wire mesh sheep hurdles tied together with bailer twine. Barrier type 3 was made with black polythene suspended from bamboo canes between water filled plastic barrels, and barrier type 4 was constructed in exactly the same fashion using clear polythene. The size was chosen so that there was room for all of the sheep to lie next to any one barrier type, and the pen spacing to accommodate all of the barriers without obstructing sheep movement around the pen.

The barriers were rotated every four days, so that there was no association between these and particular parts of the pen. The

FIGURE 4.2

AREAS WITHIN PEN USED FOR BARRIER CHOICE TRIAL



sheep were given 2 days to acclimatise to being housed initially and then 2 days with the barriers in their first position. Observations were done over the next 2 days. The barriers were then moved to their next position, such that each construction was in the position of another. After a further 2 day acclimatisation period, observations were then done over the next 2 day period. This procedure was repeated until all of the barriers had occupied each of the positions shown in Figure 4.1 with 2 days of observation in each case.

Observation was carried out using time-lapse video recording. By setting for 8 frames per second a tape which would normally last for 3 hours of real time recording lasted for a 48 hour period, still giving a continuous picture. This was analysed during the acclimatisation periods. During hours of clear visibility (10.00 am to 3.00 pm), a note was made of the lying area chosen by each sheep in every instance in which it went to lie down.

RESULTS AND DISCUSSION

The areas within the pen were divided as described previously for indoor sheep, and are shown in Figure 4.2.

For each of these areas a count was made of the number of times a sheep was seen to lie down in that area. If the animal's body crossed any of the boundaries between areas shown, the area in which most of its body lay was used and in cases in which this was not clear, ie being approximately half in half between areas, that in which its head lay was used. Overall chi^2 testing against a regular uniform use of the pen showed that the use of pen areas was not uniform (chi^2= 19.6, df=7 p<0.01). Table 4.1 shows the distribution of lying sheep for each of the pen areas. These are characterised by having a particular barrier type within sheep reach or by having no barriers within sheep reach. The sheep did not use the area near to the feeder face at all and made significantly greater use of the areas associated with the back wall of the pen and barrier type 1, both characterised by having a solid non see-through barrier within sheep reach.

Previous results (Housed Sheep in Intensive Conditions) could have been due to the animals preferring the pen edges for a number of reasons. For example, it may have been due to the properties of the edges as actual barriers to sheep movement providing areas where a sheep is less likely to be disturbed, and also consequently having cleaner, warmer, less trampled straw. It could have been due to these edges providing a direction in which to look without facing other sheep as a way of avoiding the relatively close proximity and scope for aggressive encounters. It may have been due to the physical support offered by the pen walls, as something to lean against and so on. The fact that it was only the solid non see-through barriers which were used suggests that of all of these reasons, it may be the line of sight aspect which is the most important. It is interesting that the non solid barrier (type 3) which was also non see-through was treated as a physical barrier by the sheep, in contrast to its see-through counterpart (type 4) which was totally ignored as a barrier, the

TABLE 4.1

USE OF BARRIERS BY LYING SHEEP

	Frequency of use by lying sheep	
	Number of times seen to lie down	N as %
A	115*	45
B1	79*	31
B2	13	5
B3	12	4
B4	9	3
C	12	4
D	15	6
E	1**	<1

* Area used significantly greater number of times than expected given a random (regular) distribution throughout pen at $p<0.05$.

** Area used significantly less than expected given a random (regular) distribution throughout pen at $p<0.05$.

animals walking through rather than around it. Also, the see-through solid barrier was less effective as a means of avoiding an aggressive encounter than its non solid but non see-through counterpart, again suggesting that it is the sight of others close by which may be a major factor in increased arousal and aggression seen in housed sheep.

It is also interesting that there was very little aggression seen in this trial. Interaction samples were taken over 16 hours (2 hours per day for each of the 8 days used to observe lying distribution) showed that the mean rate of aggressive encounters was 2 per group of 8 sheep per 2 hour sample, or 0.03 per head per hour. Of these 9 (56%) were over feeding space, 6 (37%) were over access and only 1 (6%) over lying space.

CONCLUDING POINTS

1. The main features which appear to be associated with the use of the pen edges to lie near are the fact that these are non see-through and provide some physical barrier to sheep movement, being areas in which an animal is less likely to be disturbed by passing sheep and with generally cleaner less well trampled straw.

2. The low levels of aggression seen in this trial suggests that $12m^2$ per head area within the pen (split up by barriers) and 1m of feeding face per head may be an adequate substitute for the space used for feeding and lying when in extensive conditions.

MODIFIED PENS - PEN SPACE AND FEEDER LENGTH TRIAL

AIM

The aim of this experiment was to investigate the use of space by sheep kept indoors.

One of the main welfare concerns for housed animals is quite simply that they do not have enough space. In the relatively unconfined conditions of most grazing systems, sheep will lie and rest or ruminate close together, making use of the total available space only when grazing, and even then they are often to be found much closer together than their enclosure could allow (see Outdoor Sheep in Extensive Conditions). It could be suggested that when food is presented in concentrated form, as in most housed systems, they may not need to be so far apart. Alternatively, grazing behaviour may also satisfy physical and psychological needs other than food gathering, requiring the observed spacing, the lack of which may result in the increase in aggressive behaviour and competition for pen space seen in sheep housed permanently at the closest levels of proximity seen in the field. For example, in a group of animals given 1-2 m^2/head and 15cm at a feeding face there were on average two threats and one butt seen per head per hour (Section 3). In the field such overt aggression is rare ; a similar group of animals grazing 500m^2 per head showed on average only one butt per head per week.

There are also obvious restrictions on their ability to perform other behaviour patterns in their ethological repertoire, and this in itself can be considered indicative of a lack of welfare.

Although there were severe practical restrictions on facilities available, it was possible to manipulate spacing in a small group of sheep over a short period to begin to answer the question "How much space should housed sheep have? "

As a considerable amount of the competition seen in housed sheep in previous experiments concerned space specifically for feeding, it was decided to look at pen space and feeding space separately. Initially, pen space was varied, keeping feeding space constant. An optimum pen space was then chosen and kept constant while feeding space was investigated.

PEN SPACE

Materials and Methods

The shed at Glencorse was available for 24 days over the period 14th December 1986 to 6th January 1987. These limitations on time and space dictated the experimental design.

Details of the shed and animals and husbandry methods were as described in the General Materials and Methods Section.

The commercially recommended spacing of $2m^2$ per head, at which earlier observations showed the amounts of aggression instigating this set of experiments, was taken as the minimum. In a previous experiment (Barrier Choice Trial) sheep given $12m^2$ per head showed almost no aggressive competition for pen space and so this was taken as the maximum for this trial.

As a group of eight is generally regarded as the minimum allowing basic statistical analysis, and was the number used in all other experiments with some control over conditions, this was the group size used here.

This meant that at maximum spacing four groups could be fitted into the shed, allowing for the study of two of the many factors that might affect the spatial requirements of the sheep.

Due to the time restrictions on this trial, one of the most important factors to be considered was that of learning and habituation throughout the trial. As there would not have been time to repeat particular spacings within each group as a control for this, and a random variation in spacing per group would have masked the effect of direction of change in itself on the behaviour of the sheep, it was decided to have half of the sheep beginning at the smallest spacing and increasing throughout the experiment with the other half beginning at the largest spacing and decreasing. Comparison of these two treatments, later referred to as 'increasing space' and 'decreasing space' respectively, should show whether or not habituation was affecting their use of pen space.

Previous work had also shown that the space by the pen edges was regarded as a valued resource by housed sheep and that freestanding solid non see-through barriers placed in the center of a pen were used in the same way as the pen edges. These had a beneficial effect in reducing aggressive competition for pen space, and as this edge and/or barrier effect seems to substantially influence the use of pen space, this was regarded as the second most important factor to be considered in this trial. Half of the sheep with increasing space and half of those with decreasing space were given barriers (solid non see-through as described in Section 4) and had partitions giving one box or cubicle per head in their feeding trough (also solid, non see-through).

The four groups of 8 sheep then were penned as follows ;

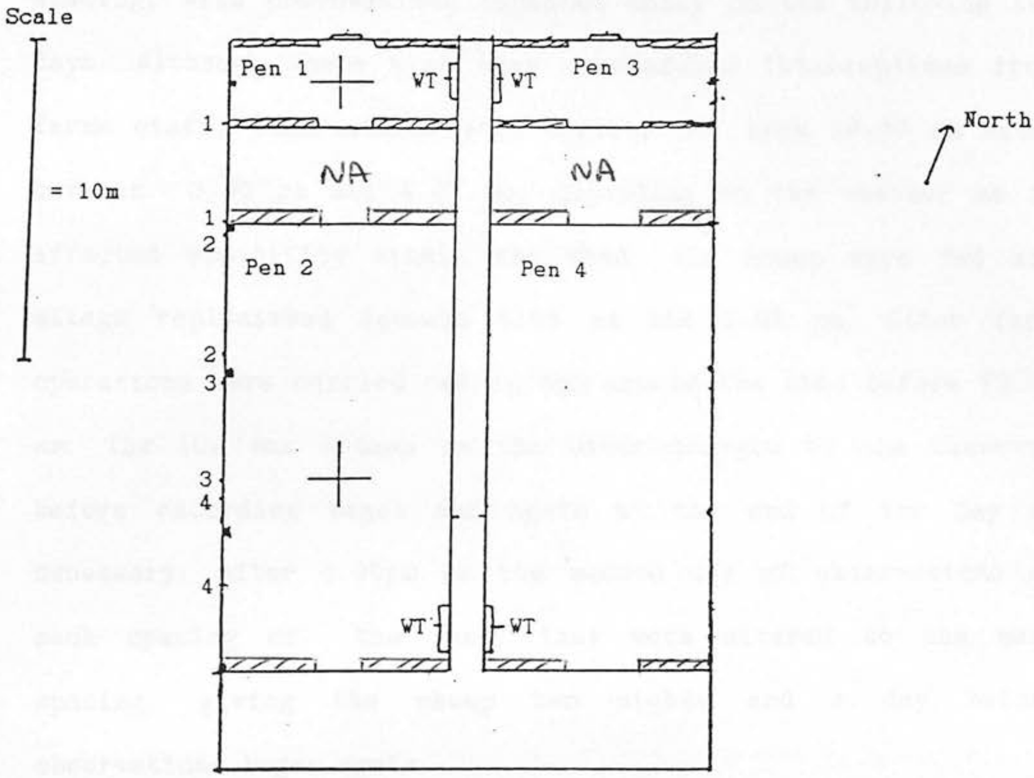
Pen 1	Space decreasing	Barriers
Pen 2	Space increasing	Barriers
Pen 3	Space decreasing	No barriers
Pen 4	Space increasing	No barriers

Ideally the shape of their pens should have remained constant, to keep the same proportion of edge length to overall pen space, but due to the limitations of space and penning materials this was not possible. The feeding troughs had to be used as the moveable pen boundaries and, although again this was not ideal, having the feeding area part of the pen edges, this is the same as in most commercial systems and previous studies and so may make these results more relevant to general discussion.

Pen space was varied incrementally from 12m^2 per head through 9m^2 per head and 5m^2 per head to 2m^2 per head for groups with pen space decreasing and vice versa for those with pen space increasing. There was 1.5m of feeding space per head. The concentrates were sprinkled onto the silage when this was replenished daily. The boundary positions are shown along with the pen layout within the shed in Figure 5.1.

FIGURE 5.1

PEN LAYOUT AS USED FOR THE SPACE AND FEEDER LENGTH TRIAL



Position of feed boxes NA This area was not available to the sheep

Position of barriers

WT Water source

Numbers 1 to 4 show the positions of the pen boundaries used to provide the varying amounts of space required for the trial

When at position 1 as shown here	Pens 1 and 3 had 2m² per head
	Pens 2 and 4 had 12m² per head
When at Position 2	Pens 1 and 3 had 5m² per head
	Pens 2 and 4 had 9m² per head
When at Position 3	Pens 1 and 3 had 9m² per head
	Pens 2 and 4 had 5m² per head
When at Position 4	Pens 1 and 3 had 12m² per head
	Pens 2 and 4 had 2m² per head

The sheep were given one day to acclimatise to their new pen spacing, with observations repeated daily on the following two days. Although there were many unscheduled interruptions from farms staff, observations were carried out from 10.00 am until between 3.00 pm and 4.00 pm, depending on the weather as it affected visibility within the shed. The sheep were fed and silage replenished between 4.00 pm and 6.00 pm. Other farm operations were carried out in and around the shed before 10.00 am. The ice was broken on the water troughs by the observer before recording began and again at the end of the day if necessary. After 6.00pm on the second day of observations at each spacing of the pens, they were altered to the next spacing, giving the sheep two nights and a day before observations began again.

As it was the positions of the sheep within their pen and the aggressive competition which was of primary interest in this trial, behaviour was recorded by scan sampling along with interaction sampling between scans. Scans were taken of all groups every 15 minutes, with alternate 10 minute interaction samples on two groups, so that overall 1,280 minutes of interaction sampling and 597 scans were done.

Scan and interaction sampling were done in exactly the same way as described previously for indoor sheep.

RESULTS AND DISCUSSION

Pen Space

Three different ways were chosen to attempt to measure the spatial requirements of these sheep.

The level and nature of the aggressive competition was taken from the interaction samples. Theoretically there will be some point at which there will be enough pen space for all of the sheep beyond which such competition for pen space will no longer be necessary.

There may be many other factors involved in overt interactions, for which it was not possible to control in this trial, and an alternative physical method was also chosen to look at the same principle. Social animals such as sheep will not spread themselves out indefinitely, but reach a point beyond which group cohesion is maintained. Therefore, the actual pen space occupied by the group relative to the total available pen space was measured, from the scan samples, to see if this point was reached under these experimental conditions.

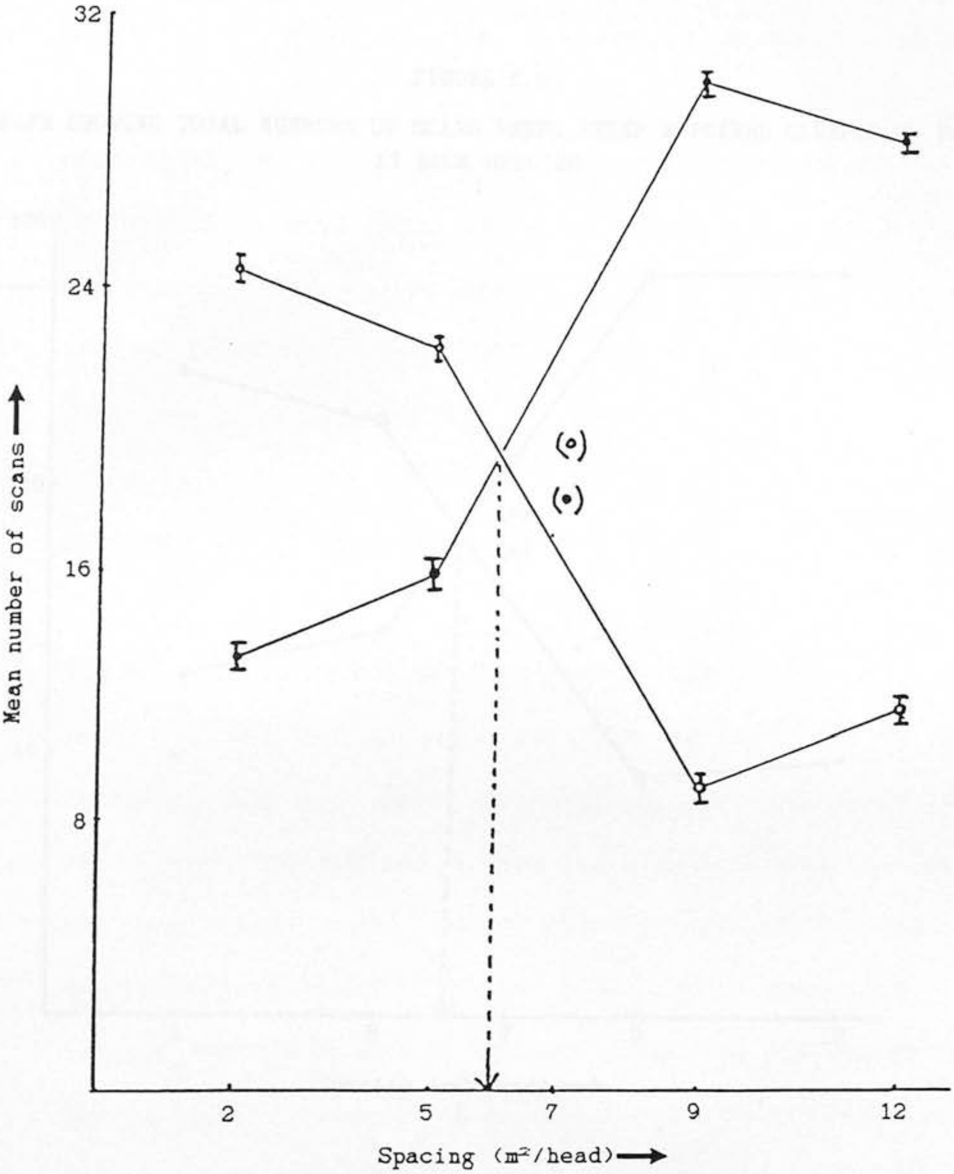
However, such a technique puts emphasis on the farthest distances between the animals. Another method was sought which would make use of the closest distances between sheep. That described by Innes, Balph and Balph (1985) was attempted, where a mathematical function can be plotted of mean nearest neighbour distances for a given number of randomly separated animals, depending on enclosure size and shape. In an ideal enclosure the mean nearest neighbour distance found in unrestricted animals would be the same as the random separation of that number of animals in that enclosure ie. on average they would be their preferred distance apart. Animals in too small an enclosure would be found on average to be further apart than expected given a random distribution, appearing visually as spread out throughout the whole of the enclosure. Those in too large an enclosure (in terms of efficient use of pen space) would be found closer than expected given a random distribution, appearing visually clumped within the enclosure. It was not possible to apply the exact function used by Innes et al (1985) directly to the results of this trial (Balph 1988 pers. comm.), but an approximation of the technique was made by scoring each scan according to the visual effect of the spread of the animals throughout the pen as clumped or not.

Visual Asssessement of Scans

Each scan sample was visually assessed and the distribution of animals throughout the pen scored as clumped or not. All four pens had each spacing throughout the trial and each pen represents a different set of treatments. These data are represented graphically in Figure 5.2, using the means of the four pens and Figure 5.3 using the totals. The cross-over point on each graph shows the pen spacing at which clumping becomes obvious in most scans. This occurs between pen spacings of $9m^2$

FIGURE 5.2

GRAPH SHOWING MEAN NUMBERS OF SCANS WHERE SHEEP APPEARED CLUMPED OR NOT AT EACH SPACING



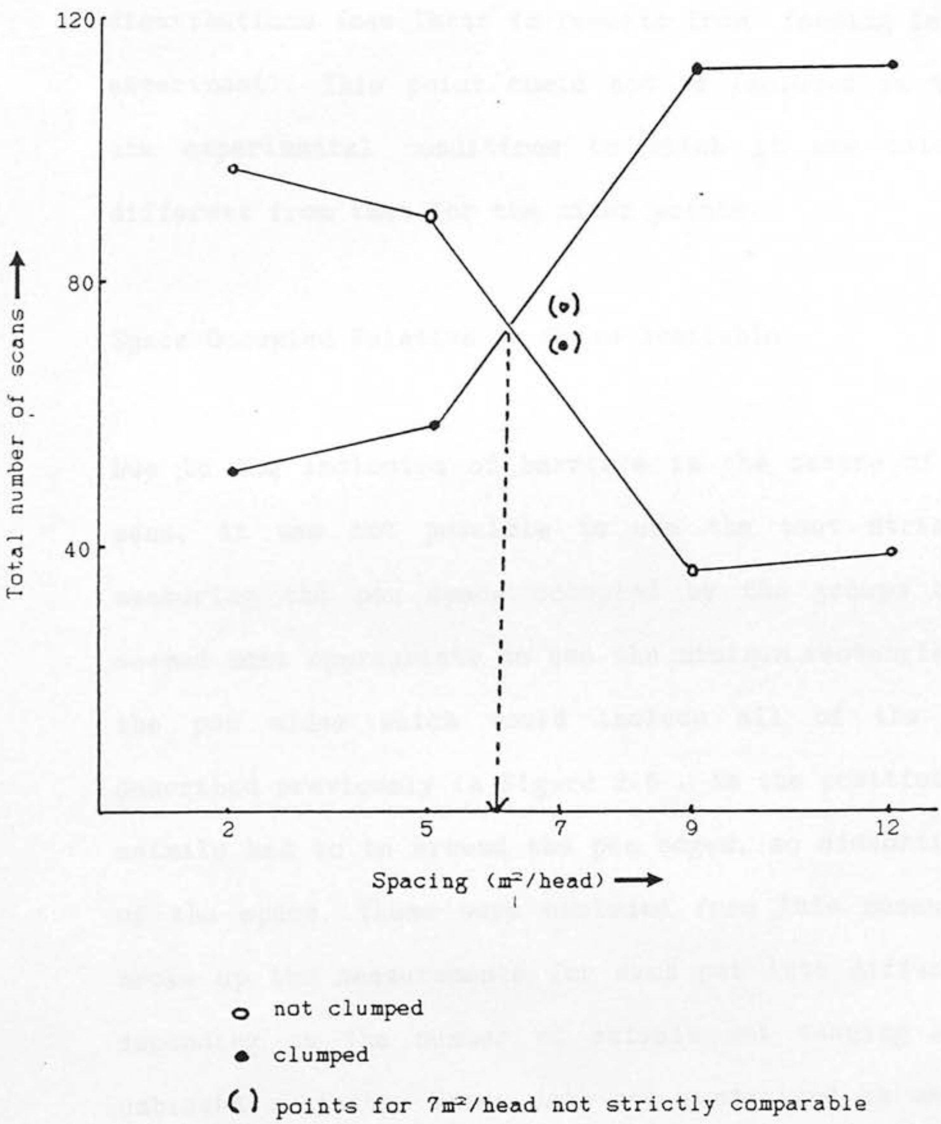
o not clumped

• clumped

I error bars = SE of mean over all 4 treatments

( ) points for 7m²/head not strictly comparable

FIGURE 5.3
GRAPH SHOWING TOTAL NUMBERS OF SCANS WHERE SHEEP APPEARED CLUMPED OR NOT AT EACH SPACING

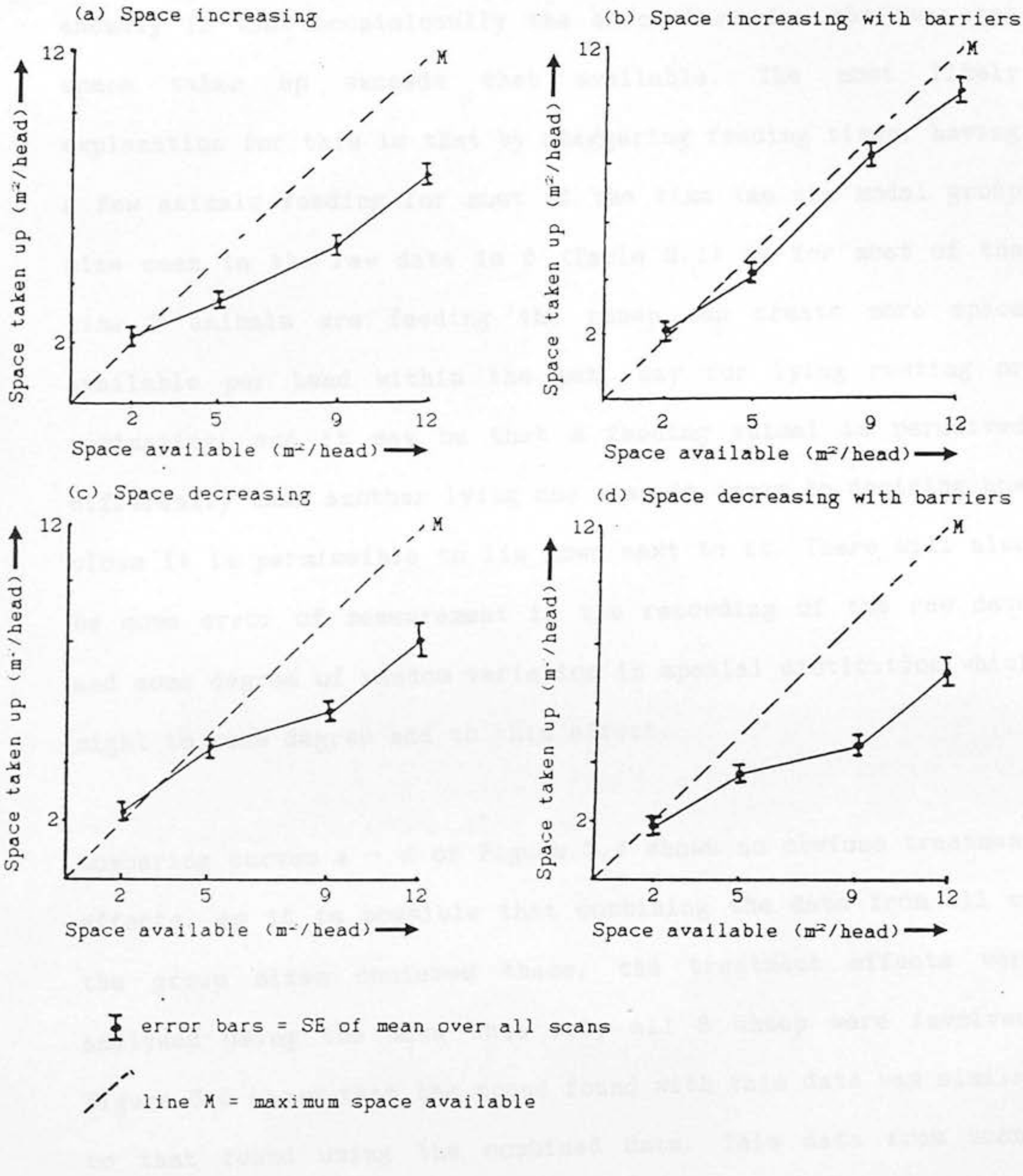


per head and $5m^2$ per head. While this is a very rough estimation of ideal enclosure size, it does put one measure of an optimum between these points. It is interesting that while the simple graphical extrapolation puts the cross-over optimum at less than $7m^2$ per head, the data from groups at this spacing during the feeding space trial show a slight preponderance of non-clumped distributions (see later in results from feeding length part of experiment). This point could not be included in the graph as the experimental conditions in which it was calculated were different from that for the other points.

Space Occupied Relative to Space Available

Due to the inclusion of barriers in the centre of some of the pens, it was not possible to use the taut string method of measuring the pen space occupied by the groups of sheep. It seemed most appropriate to use the minimum rectangle parallel to the pen sides which would include all of the animals, as described previously in Figure 2.6 . As the positions of feeding animals had to be around the pen edges, so distorting their use of the space, these were excluded from this measurement. This broke up the measurements for each pen into different sections depending on the number of animals not feeding and so being unbiased subjects. These data are summarised as mean pen space taken up per head for each number of non feeding sheep and for each spacing . This is represented graphically in Figure 5.4 to show how the mean pen space taken up per head varies with the total available pen space per head. As can be seen from Figure

FIGURE 5.4
GRAPHS SHOWING HOW SPACE TAKEN UP VARIES WITH MAXIMUM SPACE AVAILABLE FOR EACH TREATMENT GROUP (a - d)

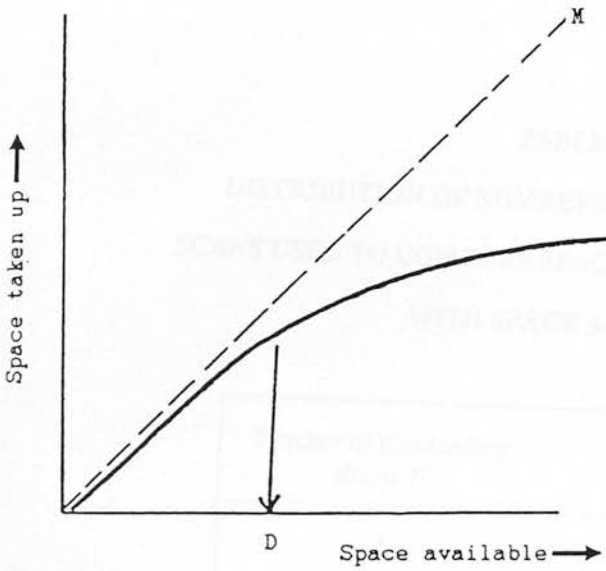


5.5, the shape of these curves generally follows the expected trend, with the point of divergence putting the optimum spacing by this method around the $5m^2$ per head mark. There is a slight anomaly in that occaisionally the error bars for the mean pen space taken up exceeds that available. The most likely explanation for this is that by staggering feeding times, having a few animals feeding for most of the time (as the modal group size seen in the raw data is 6 (Table 5.1) ie for most of the time 2 animals are feeding the sheep can create more space available per head within the pen, say for lying resting or ruminating; and it may be that a feeding animal is perceived differently than another lying one when it comes to deciding how close it is permissible to lie down next to it. There will also be some error of measurement in the recording of the raw data and some degree of random variation in spatial distibution which might to some degree add to this effect.

Comparing curves a - d of Figure 5.4 shows no obvious treatment effects. As it is possible that combining the data from all of the group sizes confuses these, the treatment effects were analysed using the data when only all 8 sheep were involved. Figure 5.6 shows that the trend found with this data was similar to that found using the combined data. This data from scans with all 8 animals non feeding would give the most accurate picture, not muddled by differential perception of feeding sheep. Here it would appear that when pen space is increasing, the barriers increase the amount of pen space taken up, wheras when pen space is decreasing, the barriers decrease the pen

FIGURE 5.5

THEORETICAL CURVE FOLLOWED BY SPACE TAKEN UP BY THE SHEEP RELATIVE TO MAXIMUM SPACE AVAILABLE



line M = maximum space available

D = Point of divergence of theoretical curve from the line of maximum space available indicating optimim space required by the sheep

TABLE 5.1

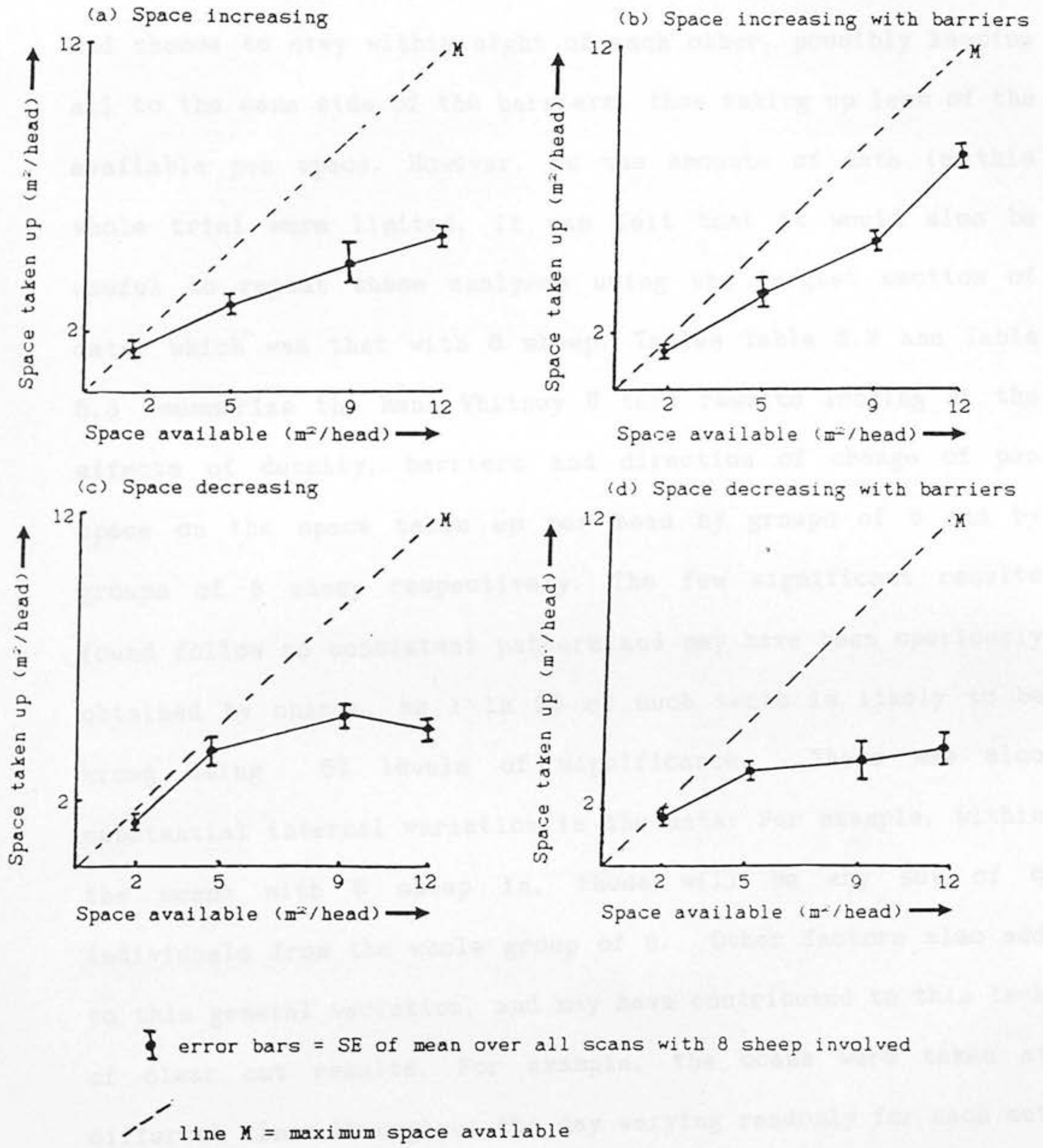
DISTRIBUTION OF NUMBERS OF SHEEP INVOLVED IN SCANS USED TO COMPARE SPACE OCCUPIED BY THE SHEEP WITH SPACE AVAILABLE

Number of non-feeding sheep N	Number of scans with N sheep
2	35
3	54
4	80
5	93
6	127
7	98
8	86

Note:
Scans with only one sheep non-feeding could not be used to measure space occupied by the sheep and so are not included here.

FIGURE 5.6

GRAPHS SHOWING HOW SPACE TAKEN UP VARIES WITH MAXIMUM SPACE AVAILABLE FOR EACH TREATMENT GROUP (a - d) USING ONLY DATA WITH ALL 8 SHEEP INVOLVED IN THE SCAN SAMPLE



space used. It may be that aggressiveness or fearfulness is learned when pen space is initially very limited, and later when given the chance, extra pen space is made use of along with the barriers possibly to hide behind. On the other hand, if there is initially enough pen space, the group may learn cohesive habits and choose to stay within sight of each other, possibly keeping all to the same side of the barriers, thus taking up less of the available pen space. However, as the amounts of data in this whole trial were limited, it was felt that it would also be useful to repeat these analyses using the largest section of data, which was that with 6 sheep. Tables Table 5.2 and Table 5.3 summarize the Mann Whitney U test results looking at the effects of density, barriers and direction of change of pen space on the space taken up per head by groups of 6 and by groups of 8 sheep respectively. The few significant results found follow no consistent pattern and may have been spuriously obtained by chance, as 1 in 20 of such tests is likely to be wrong using 5% levels of significance. There was also substantial internal variation in the data. For example, within the scans with 6 sheep in, these will be any set of 6 individuals from the whole group of 8. Other factors also add to this general variation, and may have contributed to this lack of clear cut results. For example, the scans were taken at different times throughout the day varying randomly for each set of treatments. There was also a relatively small sample size to begin with, and errors of measurement in the recording of the data.

TABLE 5.2

EFFECT OF VARIOUS TREATMENTS ON SPACE OCCUPIED BY GROUPS OF SHEEP AT EACH SPACING USING SCANS WITH 6 SHEEP INVOLVED

Treatment	Mann-Whitney test result and associated probability - U (p)			
	Spacing (m^2/head)			
	2	5	9	12
Direction of change of spacing without barriers	5.5 (0.38)	7.0 * (0.01)	15.5 (0.53)	32.0 (0.82)
Direction of change of spacing with barriers	16.5 * (0.02)	8.5 (0.91)	4.0 * (0.003)	6.5 * (0.001)
Presence of barriers with space increasing	5.0 (0.19)	3.0 (0.27)	3.5 * (0.003)	11.0 (0.22)
Presence of barriers with space decreasing	39.5 (0.90)	15.0 (0.06)	32.0 (0.96)	47.0 (0.11)

*indicates significant effect (when $p < 0.05$)

TABLE 5.3

EFFECT OF VARIOUS TREATMENTS ON SPACE OCCUPIED BY GROUPS OF SHEEP AT EACH SPACING USING SCANS WITH 8 SHEEP INVOLVED

Treatment	Mann-Whitney test result and associated probability U (p)			
	Spacing (m^2/head)			
	2	5	9	12
Direction of change of spacing without barriers	10.0 (0.37)	NA	5.5 (0.79)	3.5 (0.26)
Direction of change of spacing with barriers	14.5 (1.00)	8.5 (0.37)	4.0 (0.19)	0.0 * (0.001)
Presence of barriers with space increasing	7.0 (0.35)	2.5 (0.25)	3.0 (0.40)	0.0 * (0.002)
Presence of barriers with space decreasing	19.0 (0.94)	NA	7.0 (0.31)	8.0 (0.50)

*indicates significant effect (when $p < 0.05$)

NA only one figure in this category so test was not appropriate

As no significant treatment effects were proven using this technique, it is theoretically possible to combine all treatments, substantially increasing sample size, and measure the overall pattern of use of extra pen space when available. Tables Table 5.4 and Table 5.5 (using data from all treatment groups with 6 and 8 sheep respectively) show that for both sets of data the sheep are in most cases occupying significantly ($p < 0.05$) more pen space when the space available increases from $2m^2$ per head to $12m^2$ per head. The trends are easier to see in Figures 5.4 and 5.6. From Figure 5.4, using data from all scans combined irregardless of the number of non feeding sheep, all treatment groups continue to occupy significantly more space right up to the final increase to $12m^2$ per head. This would put the spatial requirements of these sheep at $12m^2$ per head or higher. However, using the data when all 8 animals were included as non feeding, the final increase from 9 - 12 m^2 per head is not significant for 3 out of the 4 treatment groups (see Figures 5.4 and 5.6). While this is only a small sample of the data it is probably the most reliable estimator of spatial requirements as here the whole group is involved. It is however surprising that the data including times when fewer animals are involved gives a greater spatial requirement. It could be that the occaisons when all of the sheep are lying down are those similar to camping at night when the sheep tend to lie closer than during the day between feeding bouts.

This method then puts the spatial requirements of these sheep between 9 and 12 m^2 per head and possibly over 12 m^2 per head.

TABLE 5.4

EFFECT OF SPACING ON SPACE OCCUPIED BY GROUPS OF SHEEP WITH VARIOUS TREATMENTS USING SCANS WITH 6 SHEEP INVOLVED

Spacings compared (m^2/head)	Mann Whitney test results and associated probability U (p)				
	Treatments				
	All treatments combined	Space increasing without barriers	Space increasing with barriers	Space decreasing without barriers	Space decreasing with barriers
2 and 5	50.0 * (0.0)	3.0 (0.08)	0.0 * (0.04)	0.0 * (0.0006)	4.0 * (0.004)
5 and 9	166.5 * (0.0001)	3.5 * (0.004)	0.0 * (0.04)	21.0 * (0.0)	30.5 (0.10)
9 and 12	415.0 * (0.02)	11.5 (0.43)	20.5 (0.28)	16.0 * (0.03)	48.0 (0.44)

* indicates significant effect (when p <0.05)

TABLE 5.5

EFFECT OF SPACING ON SPACE OCCUPIED BY GROUPS OF SHEEP

WITH VARIOUS TREATMENTS USING

SCANS WITH 8 SHEEP INVOLVED

Spacings compared (m^2/head)	Mann Whitney test results and associated probability U (p)				
	Treatments				
	All treatments combined	Space increasing without barriers	Space increasing with barriers	Space decreasing without barriers	Space decreasing with barriers
2 and 5	0.0 * (0.0)	0.0 * (0.08)	0.0 * (0.04)	NA	0.0 * (0.0007)
5 and 9	63.5 * (0.0001)	0.5 (0.004)	0.0 (0.04)	NA	24.5 (1.0)
9 and 12	150.0 [a] (0.0505)	4.0 (0.26)	0.0 * (0.002)	3.0 * (0.25)	17.0 (0.72)

* indicates significant effect (when $p < 0.05$)

NA only one figure in this category so test was not appropriate

[a] figure would be significant if rounded off to 2 decimal places

This estimate is larger than the previous one as would be expected as it is based on the maximum separation of the sheep and requires consideration along with other results before final recommendations can be made.

Interaction Samples

Initially, as a check on the individual interactivity of the sheep used, the total numbers of interactions measured over the whole trial (ie at every spacing) were taken for each group. Altogether there were 385 interactions seen in 32 sheep over 1280 minutes. The totals for individual animals were summarised according to treatment group or pen in Table 5.6. Both differences in total numbers of interactions seen in each group and in the spread or pattern of these between individuals were considered.

The results of a chi squared test on the data from Table 5.6 show that there was a significant difference between groups in total numbers of interactions seen chi sq = 14.84, 3df). Pen 4 with pen space increasing and barriers had fewer interactions than the rest. This may have been due either to the individuals making up this group, possibly being more familiar with one another or being less active, or to the effects of their particular combination of treatments, possibly with initial pressure on resources and motivation for aggressive competition being so great (with least pen space and no extra edges or

TABLE 5.6

DISTRIBUTION OF NUMBERS OF AGGRESSIVE INTERACTIONS OVER WHOLE TRIAL BETWEEN TREATMENT GROUPS

Pen	Treatment	Number of interactions		
		Mean (per head over whole trial)	(± SE)	Total (per pen over whole trial)
1	Space decreasing with barriers	14.8	(± 3.7)	118
2	Space increasing with barriers	11.8	(± 2.9)	94
3	Space decreasing without barriers	13.3	(± 2.4)	106
4	Space increasing without barriers	8.4	(± 2.8)	67

places to get away from each other) that they developed a stable social strategy more quickly than the other groups. If the latter were the case, it would be expected that the treatment effects would show up consistently in later analysis. This was not found to be the case, where a pen space and barrier interaction did not prove to be a significant treatment factor. No factor such as age or liveweight range was found to separate the sheep in pen 4 from the others. If there was a genuine group difference, ie due to the sample of individuals making up that group, this would not adversely affect the outcome of tests on spatial requirements, the primary objective of this series of experiments, as these were made within treatment groups, although it is a point to bear in mind when discussing these. There are no significant differences seen when using the standard error of the means (see Table 5.6) and, although this is a less accur ate measure of these differences than a test such as chi^2 on the total figures, this does validate the continued analysis of the 4 treatment groups combined as samples of one population. All tests were initially carried out on both the raw data and that adjusted to allow for differences in total numbers of interactions seen between groups and as there were no qualitative differences in the results seen, that for the raw data was used and is the source of all figures quoted in this thesis.

Due to the limits on observation time it was not possible to score interactions between all possible pairs of individuals in each group. Some pairs competed aggressively more often than others, but as there were no significant differences in terms of numbers of such pairs between groups, it was considered reasonable to use this data look at treatment effects as well as spatial requirements.

The short time span of this trial also meant that results could have been biased by learning or habituation over the course of the trial. Although it was intended to control for this by the splitting of the sheep into pen space increasing or pen space decreasing groups, it was just possible that the direction of change of pen space could in itself be an influential factor. Looking at all pens or treatment groups taken together, tests showed no significant differences in the numbers of interactions seen over time (chi sq = 0.538 , 3df).

As it was felt that the nature as well as the number of the interactions measured was useful in elucidating these animals' requirements for pen space, all of the tests in this section were carried out not only on interaction numbers, but also on numbers of threats and numbers of butts.

On average over this whole trial there were 1.1 aggressive interactions, 1.5 threats and 1 butt per head per hour. It should be remembered when considering these from a welfare point of view that these were not evenly spread throughout the day, but concentrated at such periods as the beginning and ending of feeding bouts when there was a particular demmand for lying space or access within the pen.

Most aggressive interactions, concerned direct competition over an identifiable resource. As shown in Table 5.7, most were found to occur over feeding space and pen space. The 'pen space' category here includes space for access or right of passage through the pen as well as for space to lie. Most aggressive interactions were also instigated by the winner of the resource eg. in 343 interactions the recipient was displaced from the resource involved, compared to 13 in which it was the instigator who was displaced with 25 instances where there was no obvious displacement of either individual. From Table 5.8 it can be seen that there is a tendency for individuals to be primarily an instigator or primarily a recipient of these interactions and so be generally one which displaces others or is usually displaced. These distinctions were significant (eg. chi^2 = 120.7 for instigators and 102.1 for recipients with 2 degrees of freedom) and are those reflected later when referring to individuals as 'successfully competitive' or 'non competitive'. The distribution of numbers of successfully competitive and non competitive sheep was similar in all four groups.

Data from the interaction samples, summarised as Table 5.7, are represented graphically as Figures 5.7 - 5.9 to show how these vary with space.. The numbers of interactions, threats and butts are recorded separately, and the effect of pen space is considered for these various measures of aggression or competitiveness with the major spatial resources involved of pen space, edge space or feeding space taken separately. There is a

TABLE 5.7

TOTAL NUMBERS OF AGGRESSIVE INTERACTIONS (I), BUTTS (B) AND THREATS (T) OVER MAIN RESOURCES FOR VARIOUS TREATMENTS

Treatment	Resource											
	Pen space			Edges to lie against			Feeding space			Other		
	I	B	T	I	B	T	I	B	T	I	B	T
Space decreasing with barriers	56	78	91	13	17	23	45	29	50	1	0	2
Space increasing with barriers	40	50	42	13	11	14	42	17	45	2	1	4
Space decreasing without barriers	52	70	97	11	9	14	36	40	60	2	1	4
Space increasing without barriers	18	13	31	15	15	22	34	24	29	1	1	2

TABLE 5.8

TOTAL NUMBERS OF INTERACTIONS INSTIGATED AND RECEIVED BY EACH INDIVIDUAL

Sheep number	Number of interactions (I) and received (R)							
	Pen number							
	1		2		3		4	
	I	R	I	R	I	R	I	R
1	25	13	8	8	18	6	5	16
2	12	17	3	18	8	16	1	6
3	14	5	3	14	21	24	20	6
4	29	4	23	4	7	12	4	8
5	14	8	20	16	5	21	4	7
6	3	34	4	26	14	4	21	9
7	7	26	19	7	18	11	9	4
8	14	11	14	1	15	12	3	11

FIGURE 5.7

AGGRESSION OVER SPACE

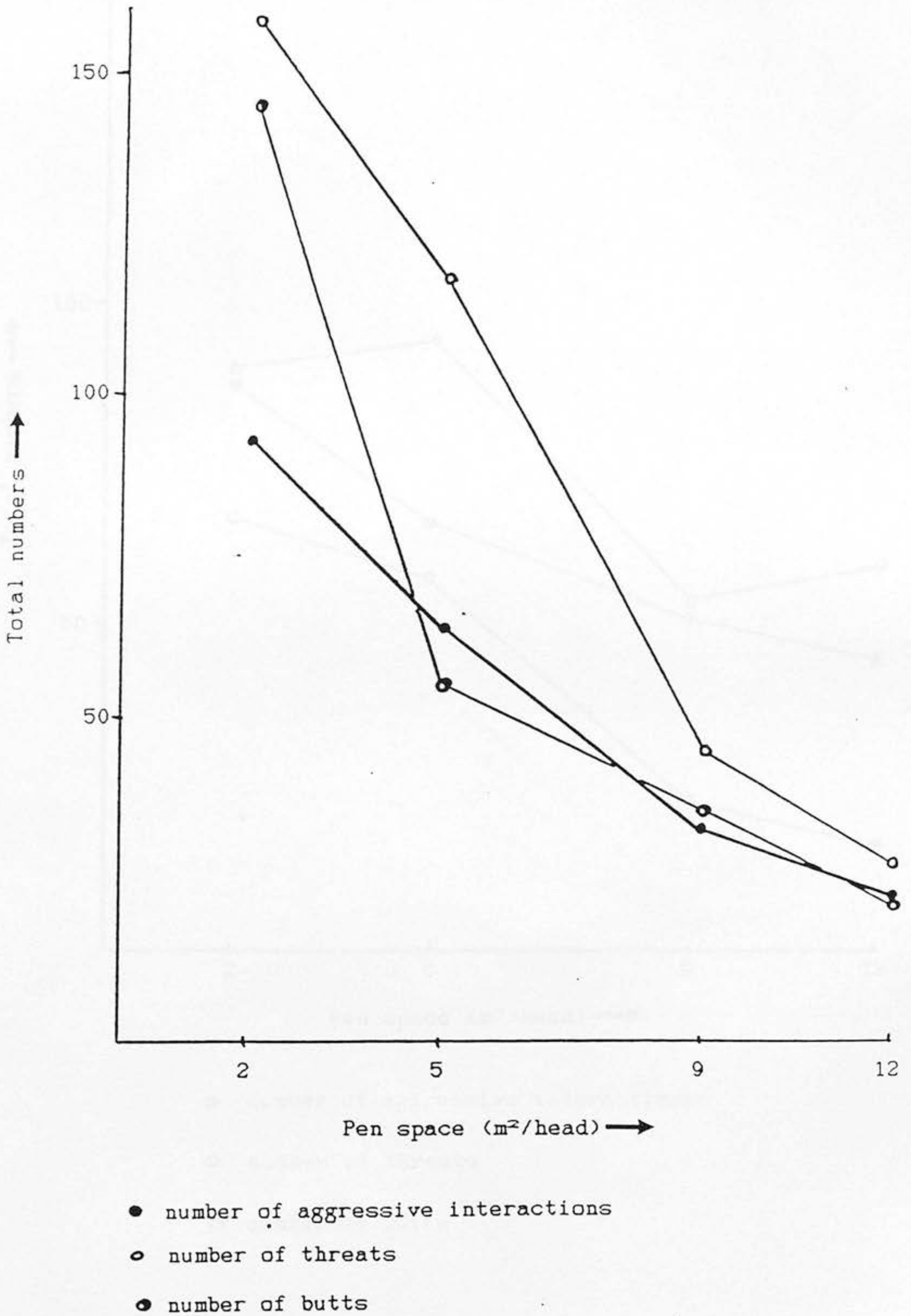
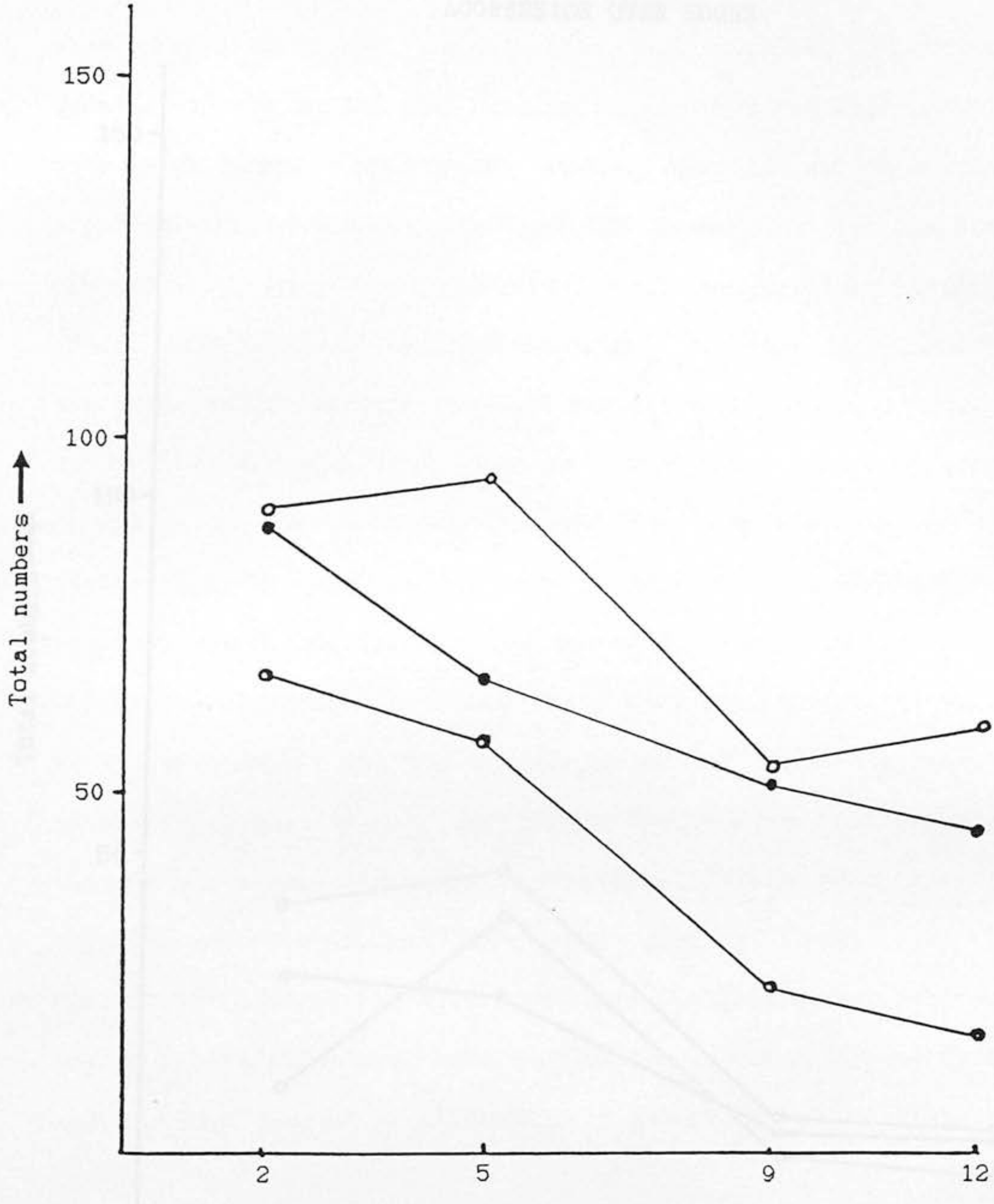


FIGURE 5.8

AGGRESSION OVER FEEDING

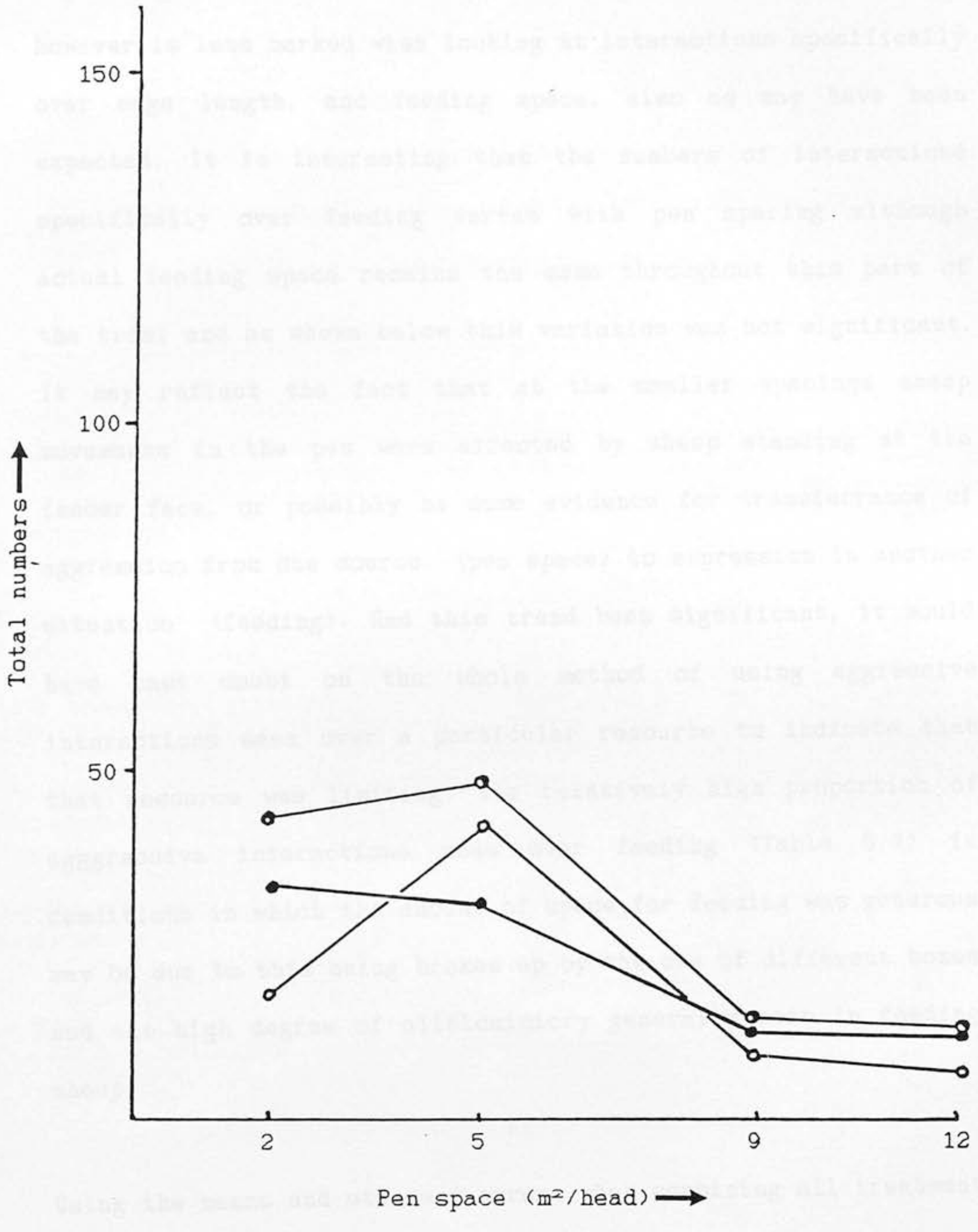


● number of aggressive interactions

○ number of threats

◐ number of butts

FIGURE 5.9
AGGRESSION OVER EDGES



● number of aggressive interactions

○ number of threats

◐ number of butts

general trend for aggression as measured by numbers of interactions, threats and butts to decrease as pen space and edge length increases, as may have been expected. The trend however is less marked when looking at interactions specifically over edge length, and feeding space, also as may have been expected. It is interesting that the numbers of interactions specifically over feeding varies with pen spacing although actual feeding space remains the same throughout this part of the trial and as shown below this variation was not significant. It may reflect the fact that at the smaller spacings sheep movements in the pen were affected by sheep standing at the feeder face, or possibly be some evidence for transferrance of aggression from one source (pen space) to expression in another situation (feeding). Had this trend been significant, it would have cast doubt on the whole method of using aggressive interactions seen over a particular resource to indicate that that resource was limiting. The relatively high proportion of agggressive interactions seen over feeding (Table 5.7) in conditions in which the amount of space for feeding was generous may be due to this being broken up by the use of different boxes and the high degree of allelomimicry generally seen in feeding sheep.

Using the means and standard errors when combining all treatment groups, the first point at which the increase in pen space no longer gives a significant decrease in aggression was noted for each measure. These points are listed in Table 5.9. While there is some variation between treatment groups and measures of

TABLE 5.9

INCREASE IN SPACING (m^2/head) BEYOND WHICH NO FURTHER SIGNIFICANT DECREASE IN AGGRESSION IS SEEN

Measure of aggression used	Treatments			
	Decreasing space with barriers	Decreasing space without barriers	Increasing space with barriers	Increasing space without barriers
Total numbers of interactions	5-9	5-9	5-9	9-12
Total numbers of threats	5-9	5-9	NS	5-9
Total numbers of butts	5-9	5-9	5-9	2-5
Numbers of interactions over space	2-5	5-9	5-9	2-5
Numbers of threats over space	2-5	5-9	NS	9-12
Number of butts over space	2-5	5-9	5-9	NS

NS means no significant decrease in aggression seen for final increase in space aggression used, this method puts the spatial requirements for sheep between 5 and 9 m^2 per head.

It was possible to separate the various treatment effects on aggression by looking at the overall numbers of threats, butts and interactions over each resource. Analysis of variance on this data after a log transformation shows that, as may have been expected, pen space itself was the single most effective factor (Table 5.10). This had a significant effect on all measures except those over feeding space which was not affected by any of the treatments used in this part of the trial, feeding space being kept constant throughout. The only other treatment factor to have any effect was that of direction of change of pen space. With decreasing pen space, there were significantly more butts seen over pen space, although when aggression was measured by numbers of interactions or threats seen over pen space this was not a significant factor. There was a general trend for the barrier treatment to decrease the aggression seen, but this was not a significant effect in the overall analysis of variance. For example, as shown in Table 5.9, the treatment of decreasing space with barriers shows a greater proportion of results putting spatial requirements at the lower end of the range (2-5 m^2/sheep), especially for measures of aggression specifically over space. The incresing space without barriers treatment has the greatest proportion of results putting spatial requirements at the higher end of the range (9-12 m^2/sheep).

TABLE 5.10

SUMMARY OF RESULTS OF ANALYSIS OF VARIANCE TEST ON VARIOUS MEASURES OF AGGRESSION

	Variance ratio		
	Treatment factors		
Measure of aggression	Amounts of space	Direction of change of space	Presence of barriers
Total number of interactions	4.1	NS	NS
Total number of threats	4.8	NS	NS
Total number of butts	4.0	NS	NS
Number of interactions over feed	NS	NS	NS
Number of interactions over space	3.8	NS	NS
Number of interactions over edges	7.2	NS	NS
Number of threats over feed	NS	NS	NS
Number of threats over space	5.7	NS	NS
Number of threats over edges	9.8	NS	NS
Number of butts over feed	NS	NS	NS
Number of butts over space	4.1	5.6	NS
Number of butts over edges	10.6	NS	NS

NS means no significant effect found (at $p<0.05$)

Variance ratios given ony when factors show significant effects

This difference in results depending on which measurement of aggression is used (ie numbers of interactions or numbers of threats or numbers of butts) is interesting and worth bearing in mind when looking at aggression in animals. Usually only actual numbers of aggressive interactions is used, whereas as shown here the nature of these interactions as shown by the numbers of threats and butts involved may also vary and be worth considering. From the point of view of assessing the welfare of the animals involved these other measures may be even more useful than actual numbers of aggressive interactions per se.

FEEDING SPACE

Materials and Methods

After a preliminary assessment of the pen space results, each group was given $7m^2$ per head while feeding space was varied. The maximum was 1.5m per head, with a minimum of 0.375m per head being the approximate length taken up physically by one animal at the feeder. Most commercial recommendations are less than this, but these do not cater for all of the animals to feed together, and it was felt that for the sake of ease of interpretation of results, this should not be made a physical impossibility during this trial. There was time for just one intermediate treatment of 0.75m per head.

The procedure during this part of the trial was exactly the same as when varying pen space. The groups and treatments remained the same. Instead of changing pen space, feeding space was altered. Those groups with barriers also had partitions within their feeding boxes. The partitions in the feeder boxes were moved as feeding space changed so that there was always one box or cubicle section per head.

The data gathered from the first of the feeding space treatments with each group at 7m^2 per head was used to provide additional information for the pen space part of this trial. While it is not directly comparable, half of the sheep having their direction of change of pen space reversed, it does give an interesting extra point in the centre of the range of treatments for later discussion.

Results

A note was made of the numbers feeding in any scan sample, the distances between neighbouring sheep, the orientation of these to each other, called orientation of pairs, and the orientation of each sheep to the feeding box, called orientation of individuals. These were calculated as described previously in Figure 2.4 (Section 2). The number feeding was additionally broken down into the numbers at each feeding box, as casual observation during the recording of the raw data suggested that allelomimicry may play some part in feeding behaviour and related aggressive interactions in particular.

Table 5.11 summarises this data, showing the distances between feeding sheep for the various treatment groups at each spacing allowance. By comparing the means and standard errors, the only significant effect found was that of direction of change of feeding space in groups with partitions at maximum spacing. As this is not reflected in any of the other treatment categories, it is most likely to be a spurious effect of the number of tests done (expecting 1 in 20 to show a significant result where there is in reality no such effect). From the mean Figures given in Table 5.11 showing the effect of the amount of feeding space available on the distances seen between feeding sheep, it would appear that despite the slight general trend for the animals to use more feeding space when this is available, this is only just significant in a few cases, notably those with feeding space decreasing. Tables 5.12 - 5.14 show the Mann Whitney U test results which corroborate these findings, calculated for each treatment, spacing and orientation category. (The calculation of orientation is described later). It may be that when feeding space is increasing, some tolerance is learned from the initial restricted feeding conditions. The situation is complicated by the unfortunate necessity of having the feeding space split into separate areas. It may be that by sheep choosing to use a separate feeding box when larger distances between feeding animals might be expected, they bias the recorded data towards the smaller, within feeding box distances. The distribution of

TABLE 5.11

DISTANCE BETWEEN FEEDING SHEEP

Treatment	Mean distance (metres) between sheep (± SE)		
	Feeding space (m/head)		
	0.375	0.75	1.125
Space decreasing with barriers	0.8 (± 0.06)	1.2 (±0.12)	1.5 (±0.16)
Space increasing with barriers	0.9 (±0.07)	1.1 (±0.10)	1.0 (±0.08)
Space decreasing without barriers	0.7 (±0.04)	1.1 (±0.08)	1.1 (±0.12)
Space increasing without barriers	0.8 (±0.05)	0.9 (±0.07)	0.9 (±0.07)

TABLE 5.12

EFFECT OF PARTITIONS ON DISTANCE

BETWEEN FEEDING SHEEP

Treatment			Mann-Whitney U test results (U) and associated probability (p) comparing groups with and without partitions	
Feeding space (m/head)	Space decreasing or increasing[a]	Orientation of sheep towards, away or parallel with each other[b]	U	(p)
1.125	D	T	29.0	(0.17)
		A	46.0	(0.30)
		P	25.0	(0.55)
	I	T	382.5	(0.70)
		A	403.0	(0.30)
		P	246.0	(0.23)
0.75	D	T	35.5	(0.90)
		A	188.0	(0.49)
		P	61.0	(0.65)
	I	T	96.5	(0.66)
		A	287.5	(0.07)
		P	100.5	(0.48)
0.375	D	T	158.0	(0.38)
		A	315.5	(0.19)
		P	101.0	(0.37)
	I	T	131.0	(0.41)
		A	134.0	(0.76)
		P	357.0	(0.16)

No significant effects seen ($p < 0.05$)

[a] D decreasing
I increasing

[b] T towards
A away
P parallel

TABLE 5.13

EFFECT OF DIRECTION OF CHANGE OF FEEDING SPACE ON DISTANCE BETWEEN FEEDING SHEEP

Treatment: Feeding space (m/head)	Treatment: With (+) or without (-) partitions[a]	Treatment: Orientation of sheep towards, away or parallel with each other[b]	Mann-Whitney U test results (U) and associated probability (p) comparing groups with increasing and decreasing feeding space: U	(p)
1.125	+	T	79.5	(0.02) *
		A	120.5	(0.02) *
		P	32.0	(0.42)
	-	T	87.0	(0.20)
		A	NA	
		P	179.5	(0.18)
0.75	+	T	30.5	(0.76)
		A	121.5	(0.75)
		P	54.0	(0.21)
	-	T	154.5	(0.96)
		A	594.5	(0.14)
		P	206.5	(0.71)
0.375	+	T	161.0	(0.47)
		A	258.0	(0.87)
		P	540.0	(0.31)
	-	T	138.0	(0.74)
		A	154.0	(0.41)
		P	141.5	(0.51)

No significant effects seen ($p < 0.05$)

NA test not appropriate as there was not enough data in this category

[a] + with
 \- without

[b] T towards
 A away
 P parallel

TABLE 5.14
EFFECT OF AVAILABLE FEEDER SPACE ON DISTANCE BETWEEN FEEDING SHEEP

Treatment	Feeder spacings compared (m/head)	Orientation of sheep towards, away or parallel with each other[b]	Mann-Whitney U test results (U) and associated probability (p) comparing groups with increasing and decreasing feeding space U	(p)
Space decreasing with partitions	1.125	T	0.0	(0.02) *
	and	A	18.5	(0.26)
	0.75	P	7.0	(1.00)
	0.75	T	15.5	(0.30)
	and	A	196.5	(0.005)*
	0.375	P	99.0	(0.24)
	1.125	T	1.5	(0.005)*
	and	A	6.5	(0.001)*
	0.375	P	16.5	(0.11)
Space increasing with partitions	1.125	T	292.5	(0.74)
	and	A	312.0	(0.31)
	0.75	P	187.5	(0.16)
	0.75	T	106.0	(0.89)
	and	A	216.5	(0.04) *
	0.375	P	87.5	(0.26)
	1.125	T	338.0	(0.96)
	and	A	372.5	(0.24)
	0.375	P	250.0	(0.44)
Space decreasing without partitions	1.125	T	31.0	(0.68)
	and	A	101.5	(0.40)
	0.75	P	151.5	(0.40)
	0.75	T	164.0	(0.68)
	and	A	544.0	(0.004)*
	0.375	P	721.0	(0.003)*
	1.125	T	30.5	(0.52)
	and	A	101.0	(0.007)*
	0.375	P	448.5	(0.003)*
Space increasing without partitions	1.125	T	204.5	(0.12)
	and	A	323.0	(0.76)
	0.75	P	260.0	(0.79)
	0.75	T	151.0	(0.59)
	and	A	53.0	(0.52)
	0.375	P	23.5	(0.28)
	1.125	T	181.0	(0.26)
	and	A	193.5	(0.51)
	0.375	P	295.0	(0.35)

No significant effects seen ($p < 0.05$)

[a] T towards; A away; P parallel

feeding animals between feed boxes was such that boxes available were often not used. For example, in all instances in which more than one animal was feeding and there was more than one feed box available, 25 % of the available boxes were not used. This effect was more marked at the larger spacings. For example at the largest spacing of 1.125m per head 37% of available boxes were not used in comparison to 13% unused at the smaller spacing of 0.75m per head. The ability to feed at different feed boxes may help to explain the ineffectiveness of the partitions on the distances between feeding animals, as animals without partitions could go to a different box and achieve the same effect as those with partitions and the allelomimicry seen in choice of feed box, especially at the larger feeding space allowances, may help to explain the high amounts of aggressive competition still seen over feeding space here in comparison with previous work (Barrier Choice Trial).

The relative constancy of distances between feeding animals is illustrated in Figure 5.10, the overall mode being 0.6 m, meaning that most sheep fed 0.6m apart.

Table 5.15 shows that there is no difference between treatments or feeding space allowances on numbers feeding together at any one time.

From the interaction samples it can be seen that there is aggressive competition for feeding space throughout the whole of this part of the trial. Table 5.16 summarises these results,

FIGURE 5.10

DISTANCES BETWEEN FEEDING SHEEP FOR VARIOUS AMOUNTS OF FEEDING SPACE AVAILABLE

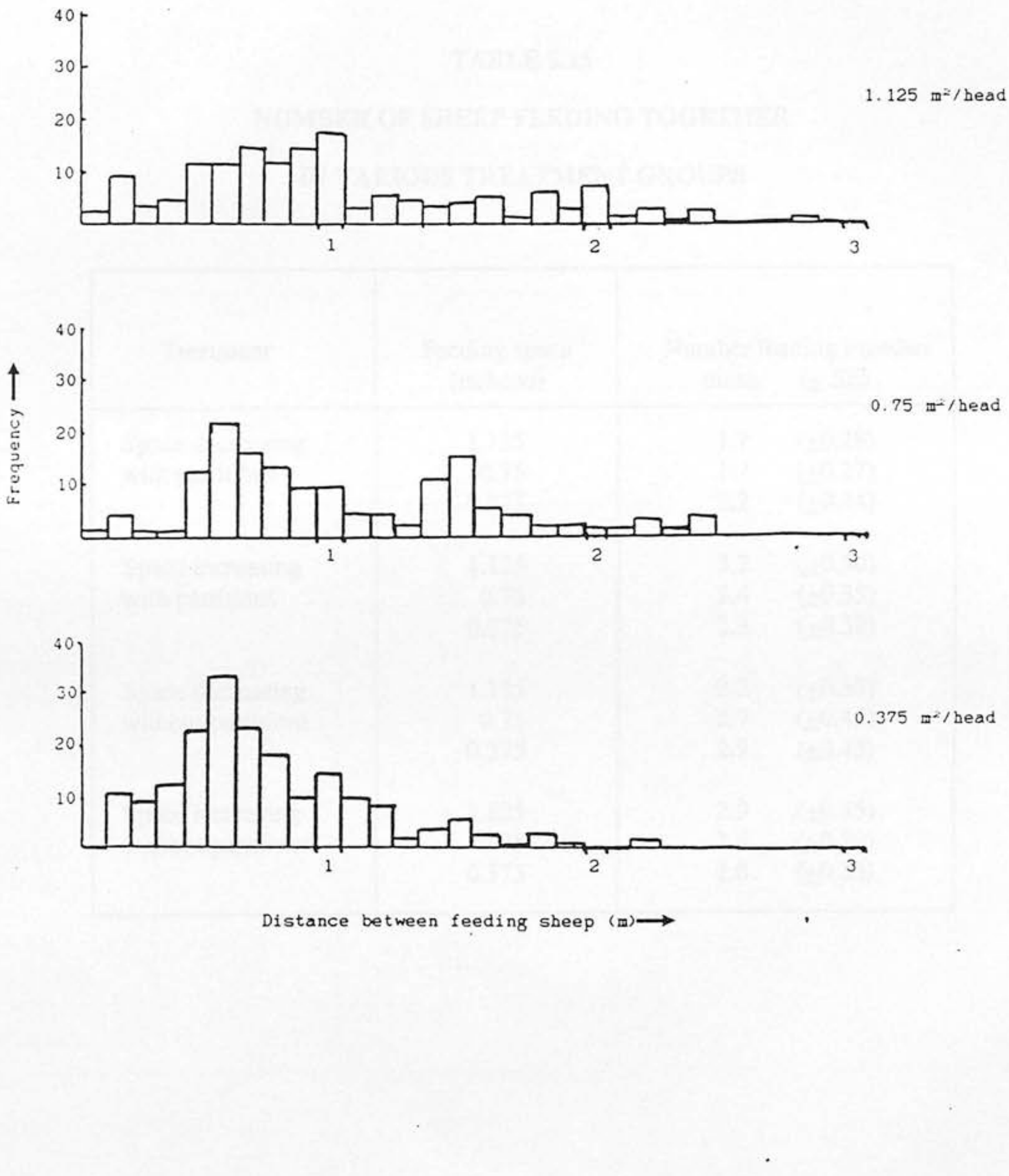


TABLE 5.15

NUMBER OF SHEEP FEEDING TOGETHER IN VARIOUS TREATMENT GROUPS

Treatment	Feeding space (m/head)	Number feeding together mean (± SE)
Space decreasing with partitions	1.125	1.7 (±0.28)
	0.75	1.7 (±0.27)
	0.375	2.2 (±0.34)
Space increasing with partitions	1.125	3.2 (±0.50)
	0.75	2.4 (±0.38)
	0.375	2.3 (±0.38)
Space decreasing without partitions	1.125	2.2 (±0.36)
	0.75	2.7 (±0.45)
	0.375	2.9 (±0.45)
Space increasing without partitions	1.125	2.9 (±0.45)
	0.75	2.5 (±0.39)
	0.375	2.0 (±0.33)

TABLE 5.16

AMOUNT OF AGGRESSION SEEN IN VARIOUS TREATMENT GROUPS OVER VARIOUS RESOURCES

Treatment	Feeder space (m/head)	Total numbers of interactions (I), butts (B) and threats (T) over each resource											
		Feeding space			Edges			Pen space			Other		
		I	B	T	I	B	T	I	B	T	I	B	T
Feeder space decreasing with partitions	1.125	6	4	7	1	1	2	2	3	3	1	0	1
	0.75	14	22	28	2	0	2	4	2	6	0	0	0
	0.375	60	68	90	2	5	7	3	8	12	0	0	0
Feeder space increasing with partitions	1.125	21	11	22	6	6	9	3	4	5	0	0	0
	0.75	10	9	18	5	3	5	3	6	2	0	0	0
	0.375	37	24	40	1	0	2	1	0	1	0	0	0
Feeder space decreasing without partitions	1.125	15	15	18	0	0	0	6	9	13	0	0	0
	0.75	46	58	100	2	1	3	8	10	19	1	0	1
	0.375	44	44	45	0	0	0	4	5	6	0	0	0
Feeder space increasing without partitions	1.125	11	13	19	1	3	4	2	4	5	0	0	0
	0.75	16	17	24	6	10	11	5	4	4	0	0	0
	0.375	44	56	62	4	5	7	0	0	0	1	1	1

showing aggression related to various treatments and resources. Table 5.17 shows which of the treatment factors have a significant effect on this aggression, using the results of an Analysis of Variance test on a logarithmic transformation of this data. As expected, feeder length significantly affects all overall measures of aggression, and specifically only those over feeding, suggesting that this was the primary source of the aggressive interactions in this part of the trial. Figure 5.11 illustrates the variation in numbers of aggressive interactions seen over feeding with available feeding space. When there is less feeding space there is more aggression. The treatments only have a significant effect on some measures of aggression, as was found previously in the pen space part of this trial. One of the most surprising of these effects was that of direction of change of feeding space, in which there was less aggression (measured by numbers of butts), when feeding space was increasing. As with pen space, it may be that sheep in conditions in which there was initially a high level of competition have more motivation to learn to avoid each other and continue to do this even when resources become less restricted.

If the animals are not using the extra space available, but still showing aggressive competition and displacement while feeding, it may be possible that there is never enough perceived feeding space during this trial to allow sociable feeding together as seen in the field, and that some other solution is required. Taking the unexpected effect of direction of change

TABLE 5.17

SUMMARY OF RESULTS OF ANALYSIS OF VARIANCE TEST

ON VARIOUS MEASURES OF AGGRESSION

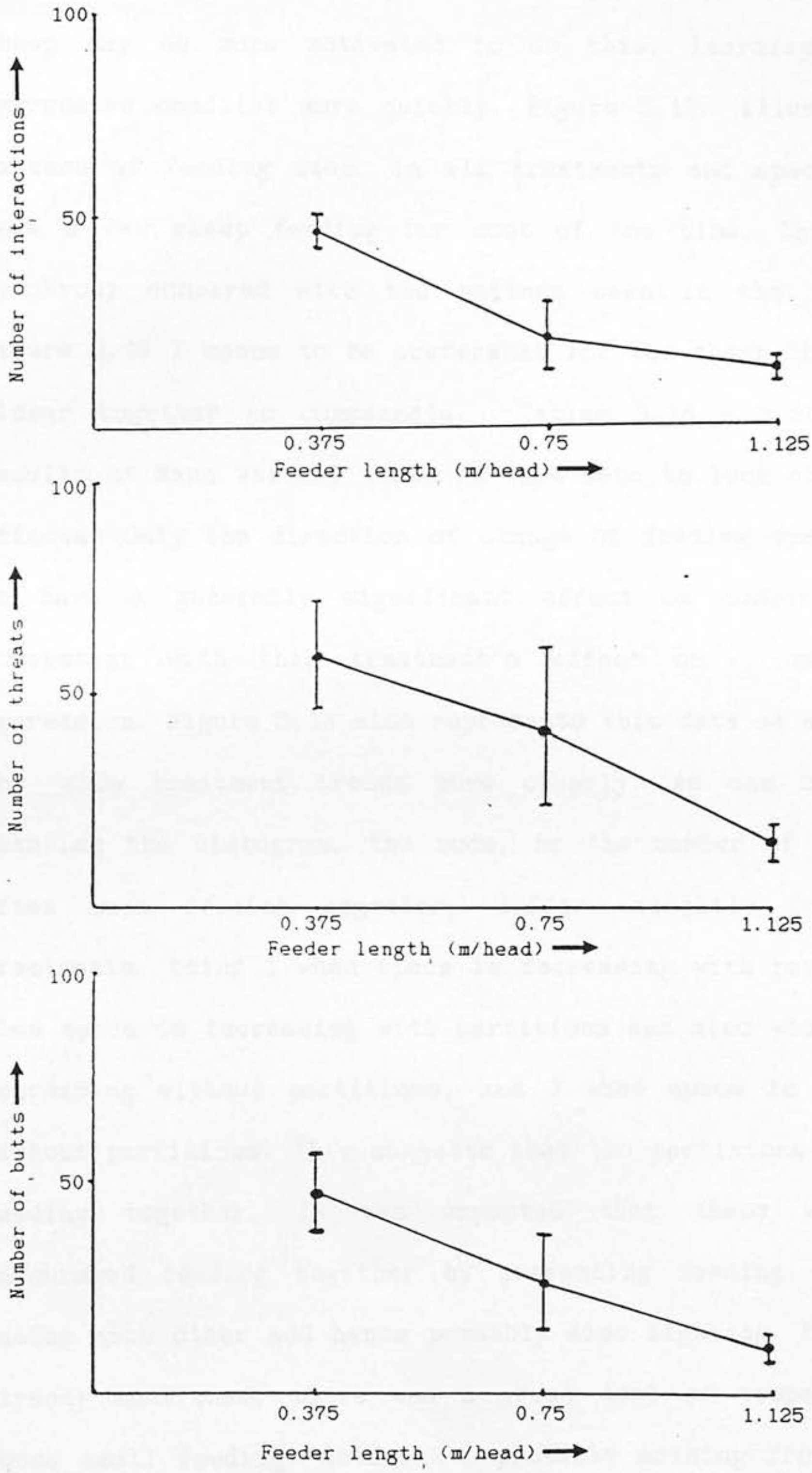
Measures of aggression	Variance ratio		
	Treatment factors		
	Feeding space	Direction of change of feeding space	Partitions
Total number of interactions	17.7	NS	NS
Total number of threats	14.9	NS	5.4
Total number of butts	6.9	NS	NS
Number of interactions over feeding space	33.6	NS	NS
Number of interactions over pen space	NS	NS	NS
Number of interactions over edges	NS	NS	NS
Number of threats over feeding space	17.3	NS	4.9
Number of threats over pen space	NS	NS	NS
Number of threats over edges	NS	NS	NS
Number of butts over feeding space	13.4	4.3	5.6
Number of butts over pen space	NS	NS	NS
Number of butts over edges	NS	4.9	NS

NS means no significant effect found (at $p < 0.05$)

Variance ratios given only when factors show significant effects

FIGURE 5.11

GRAPHS SHOWING THE RELATIONSHIP OF AGGRESSION OVER FEEDING WITH FEEDER LENGTH AVAILABLE



mean +/- SE of total numbers over all 4 treatment groups of feeding space into account, the sheep may solve their feeding space problem by dividing themselves into 'separate sittings' as it were. In pens in which there was initial high competition the sheep may be more motivated to do this, learning to avoid aggressive conflict more quickly. Figure 5.12 illustrates the pattern of feeding seen, in all treatments and spacings there were a few sheep feeding for most of the time. This lack of synchrony compared with the pattern seen in the field (see Figure 2.13) seems to be preferable for the sheep than feeding closer together to compensate. Tables 5.18 - 5.20 give the results of Mann Whitney tests on this data to look at treatment effects. Only the direction of change of feeding space appears to have a generally significant effect on numbers feeding, consistent with this treatment's effect on measures of aggression. Figure 5.13 also represents this data as a histogram to show treatment trends more clearly. As can be seen by scanning the histogram, the mode, or the number of sheep most often seen feeding together, differs slightly for various treatments, being 1 when space is decreasing with partitions, 2 when space is increasing with partitions and also when space is decreasing without partitions, and 3 when space is increasing without partitions. This suggests that the partitions discourage feeding together. It was expected that these would have encouraged feeding together by preventing feeding sheep from seeing each other and hence possibly also fighting. However, as already mentioned, there was a great deal of competition for these small feeding 'cubicles', probably arising from the high degree of social facilitation seen in sheep, and the ensueing

FIGURE 5.12

PATTERN OF FEEDING BEHAVIOUR OF FEEDING SHEEP

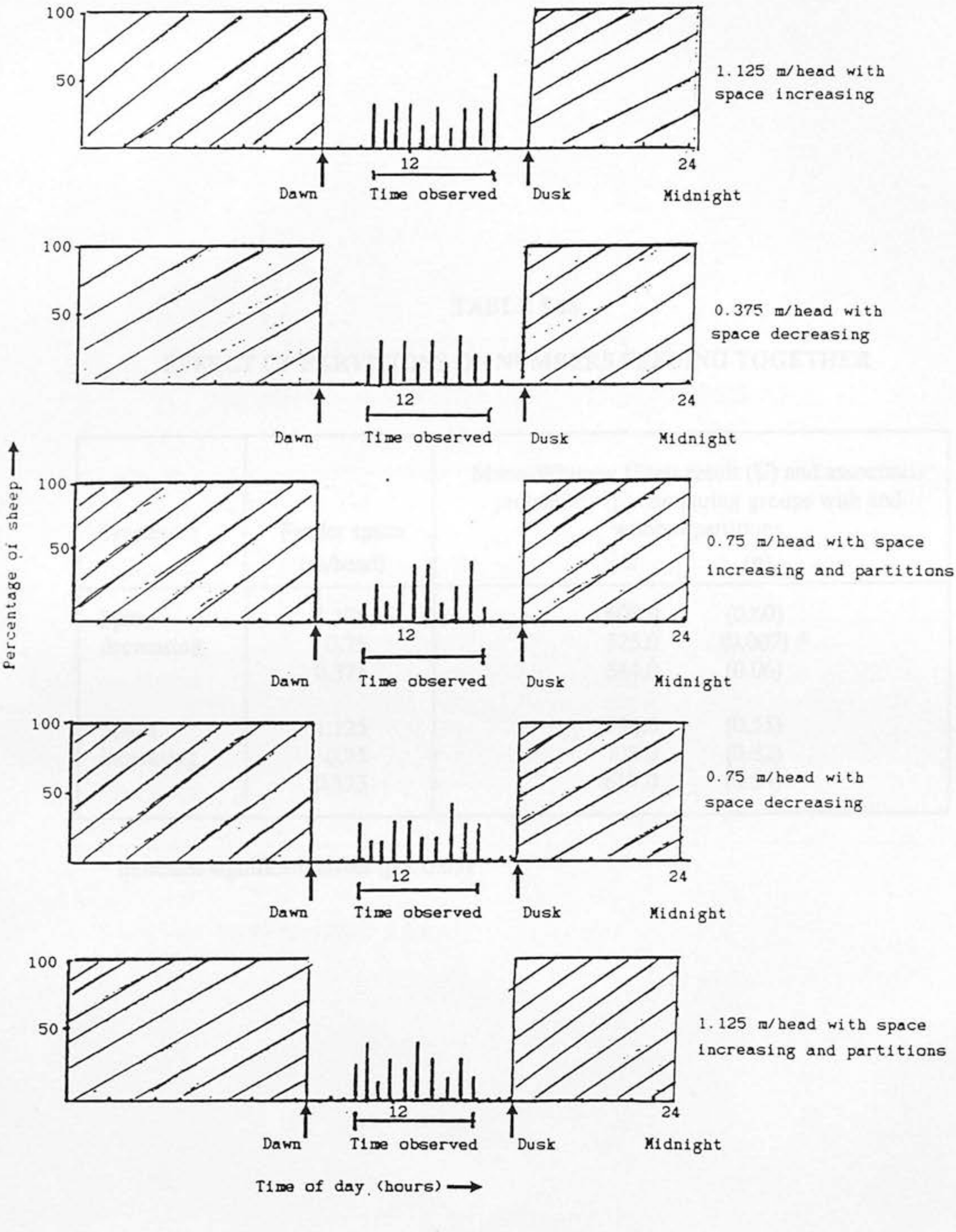


TABLE 5.18

EFFECT OF PARTITIONS ON NUMBERS FEEDING TOGETHER

Treatment	Feeder space (m/head)	Mann-Whitney U test result (U) and associated probability (p) comparing groups with and without partitions U	(p)
Space decreasing	1.125	608.0	(0.60)
	0.75	525.0	(0.007) *
	0.375	644.0	(0.06)
Space increasing	1.125	796.0	(0.55)
	0.75	778.0	(0.82)
	0.375	617.0	(0.54)

* indicates significant effect ($p < 0.05$)

TABLE 5.19

EFFECT OF DIRECTION OF CHANGE OF

FEEDING SPACE ON NUMBERS FEEDING TOGETHER

Treatment	Feeder space (m/head)	Mann-Whitney U test result (U) and associated probability (p) comparing groups with space increasing and space decreasing U	(p)
With partitions	1.125	365.0	(0.001) *
	0.75	566.0	(0.02) *
	0.375	749.0	(0.91)
Without partitions	1.125	562.0	(0.04) *
	0.75	746.0	(0.66)
	0.375	517.0	(0.01) *

* indicates significant effect ($p < 0.05$)

TABLE 5.20

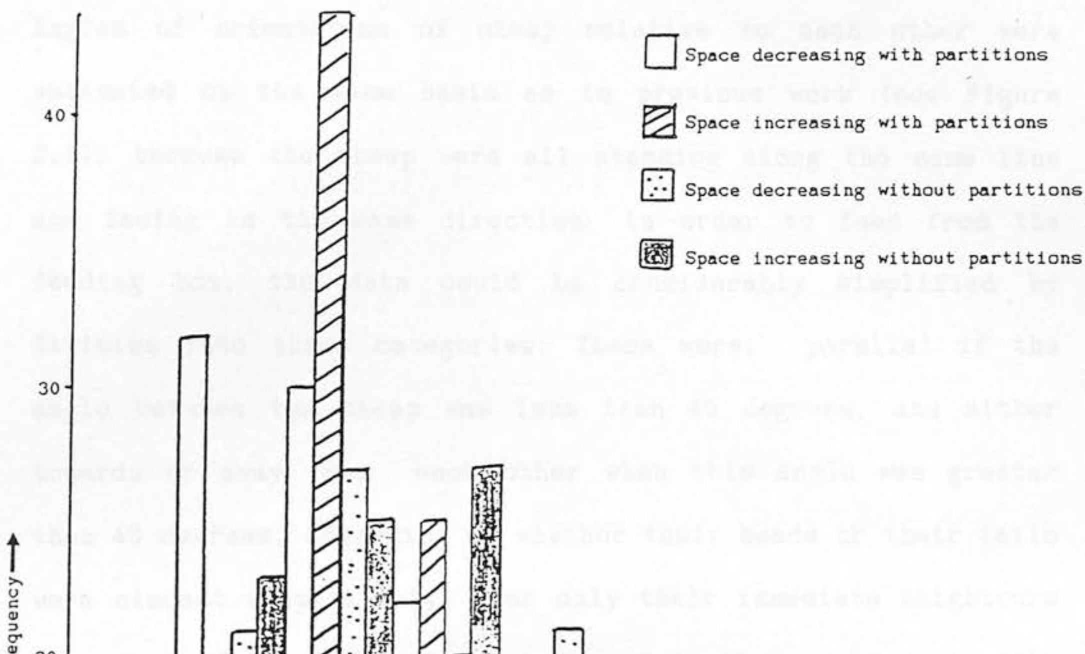
EFFECT OF FEEDER SPACE ON NUMBERS FEEDING TOGETHER

Treatment	Spacings compared (m/head)	Mann-Whitney U test result (U) and associated probability (p) U	(p)
Space decreasing with partitions	1.125 and 0.75	733.0	(0.94)
	0.75 and 0.375	650.0	(0.09)
	1.125 and 0.375	601.0	(0.10)
Space increasing with partitions	1.125 and 0.75	606.0	(0.04) *
	0.75 and 0.375	685.0	(0.57)
	1.125 and 0.375	522.0	(0.01) *
Space decreasing without partitions	1.125 and 0.75	591.0	(0.12)
	0.75 and 0.375	750.0	(0.51)
	1.125 and 0.375	550.0	(0.03) *
Space increasing without partitions	1.125 and 0.75	715.0	(0.32)
	0.75 and 0.375	629.0	(0.25)
	1.125 and 0.375	536.0	(0.02) *

* indicates significant effect ($p < 0.05$)

FIGURE 5.13

EFFECT OF TREATMENTS IN NUMBERS FEEDING TOGETHER



aggressive competition would discourage animals from actually feeding together although they do seem to try to.

Angles of orientation of sheep relative to each other were estimated on the same basis as in previous work (see Figure 2.4), because the sheep were all standing along the same line and facing in the same direction, in order to feed from the feeding box, the data could be considerably simplified by division into three categories. These were; parallel if the angle between the sheep was less than 45 degrees, and either towards or away from each other when this angle was greater than 45 degrees, depending on whether their heads or their tails were closest respectively. Also only their immediate neighbours at any one feeding box were considered as they could not really be said to be able to see any other feeding sheep. Table 5.21 gives the results of a series of Kruskall-Wallis Rank tests on the relationship of distance and orientation of sheep towards each other. A significant effect here means that there was a significant difference in distances between sheep at different orientations relative to each other. It was hoped that this might lead to some idea of the distances over which the sheep 'noticed' (eg. by way of specific orientation) each other, and so shed some light on the results obtained by looking at numbers feeding together and the distances between them. Animals closer together tended to orientate towards each other, with those farthest apart orientating away from each other. Animals seen approximately parallel to each other were spread over all distances. This result could simply be an artifact of the

FIGURE 5.21

RESULTS OF KRUSKALL-WALLIS RANK TEST COMPARING THE DISTANCES BETWEEN FEEDING SHEEP FOR VARIOUS ORIENTATIONS RELATIVE TO EACH OTHER

Treatment	Feed space (m/head)	Kruskall-Wallis (H) and associated probability (p) H (p)
Space decreasing with partitions	1.125	2.22 (0.33)
	0.75	8.75 (0.01) *
	0.375	13.22 (0.001) *
Space increasing with partitions	1.125	22.02 (0.00) *
	0.75	15.87 (0.0004) *
	0.375	10.0 (0.01) *
Space decreasing without partitions	1.125	8.15 (0.02) *
	0.75	19.02 (0.0001) *
	0.375	7.95 (0.02) *
Space increasing without partitions	1.125	22.23 (0.00) *
	0.75	14.77 (0.0007) *
	0.375	5.55 (0.006)

* indicates significant effect

measurement techniques, and the physical necessity of having to stand parallel to fit in when feeding space is restricted, and does not help with the interpretation of previous tests on their feeding behaviour.

Table 5.22 summarises the data on orientation of individuals to the feed box. Chi squared tests show that most are orientated around the perpendicular (+/- 22½ degrees) to the feeder (Chi sq = 646). This effect is more pronounced at the smaller spacings, as may have been expected. This could represent a preferrance by the sheep for feeding at around right angles to the feed box, but is more likely to be a feature of overcrowding, as this is the orientation at which an individual is least likely to be blocking another from feeding and in which it is less likely to become involved in competition for feeding space.

TABLE 5.22

ANGLE OF ORIENTATION OF FEEDING ANIMALS TO FEEDER BOX

Treatment	Feed space (m/head)	Number of sheep in each orientation category: 0 ± 22½ degrees	45 ± 22½ degrees	90 ± 22½ degrees
Space decreasing with partitions	1.125	1	37	25
	0.75	1	34	32
	0.375	0	44	48
Space increasing with partitions	1.125	0	60	69
	0.75	0	48	39
	0.375	0	22	61
Space decreasing without partitions	1.125	1	32	47
	0.75	3	44	60
	0.375	4	38	74
Space increasing without partitions	1.125	2	48	68
	0.75	0	50	49
	0.375	0	29	46

CONCLUDING POINTS

Although there were many practical problems in the interpretation of these results due to the extreme limitations of time and space available, giving rise to much variation which could not be controlled for, a few conclusions can be drawn bearing these limits in mind;

1. From the visual assessment of scans method, the value reached for the minimal spatial requirements lies between 5 and 9 m^2 per head, with no significant treatment effects seen.

2. From the comparison of space taken up with that available, the value reached for the minimal spatial requirements lies between 9 and 12 m^2 per head, with no significant treatment effects seen. There did appear to be some interaction however between the direction of change of spacing and the presence of the barriers, which could have been indicative of habituation over the period of the trial.

3. From analysis of the aggressive interactions (on average overall showing 1.1 interactions with 1.5 threats and 1.0 butts per head per hour) the first point at which an increase in space is not associated with a significant reduction in aggression puts the value reached for the minimal spatial requirements between 5 and 9 m^2 per head. The only significant treatment effect seen here was that of direction of change of pen spacing in which when this was decreasing, there were more butts seen.

4. Different results from different measures of aggression suggest that quality as well as quantity of aggressive interactions should always be taken into account and included in the analysis of treatment factors.

5. The results looking for optimum feeder length found that even at the maximum of 1.5m per head allowed in this trial, there were still a very high number of aggressive interactions. This was much higher than those seen in a previous trial (Barrier Choice Trial) with less feeding space (0.75m per head). It is suggested that the method of feeding by using separate feeder boxes may have led to this effect due to the high allelomimetic traits seen in sheep. Analysis of the pattern of feeding in these sheep also suggests that in order to avoid competition over feeding, this should be done in one single unbroken line where possible.

MODIFIED PENS TRIAL OVER SPRING 1987 AT GLENCORSE

AIM

The aim of this trial was to record the behaviour of sheep kept over the normal period of Winter housing in a pen modified according to the results of previous work in this thesis to establish the effects of these modifications on behaviour, particularly on time budgeting, use of space and numbers of aggressive interactions, as related to the assessement of the effects of housing on welfare. This could only be done for a small group of 8 animals. In addition, as much of the experimental work and that looking at sheep in extensive conditions was done with the relatively small group size of 8 it was felt necessary to include for comparison here a pen of sheep modified only by group size (of 8 rather than 30) which was typical of farm housing conditions in every other aspect.

MATERIALS AND METHODS

Two groups of eight sheep were housed over the period January to March 1987 in the shed at Glencorse.

Details of animals, shed and husbandry methods were as described in the General Materials and Methods Section.

One group was housed with $7m^2$ space per head and solid non see-through barriers in the centre of the pen. These sheep had 0.75m of feeder space each. The other group were housed with $2m^2$ space per head and no barriers with 0.25m of feeder face each. These are shown as Pen 1 and Pen 2 respectively in Figure 6.1 .

Observation methods were exactly as described for the Housed Sheep in Intensive Conditions (Groups 4 and 5).

RESULTS AND DISCUSSION

The ethogram used was that given for the Housed Sheep in Intensive Conditions (Appendix B).

The time budgets are given in tables Table 6.1 and Table 6.2. Table 6.1 shows the apportioning of time spent in each activity and Table 6.2 gives this expressed as a percentage for various combined activity patterns for ease of discussion. From the means and standard error figures given in Table 6.1, it can be seen that there are significant differences (at $p<0.05$) between these two pens for all activities. From Table 6.2 it can be more clearly seen that while the overall amounts of ruminating and lying are similar, those in the larger pen (Pen 1) spent more time feeding and resting and considerably less time standing and alert than those in the small pen (Pen 2).

FIGURE 6.1

AREA OF SHED AT GLENCORSE USED FOR MODIFIED PENS TRIAL

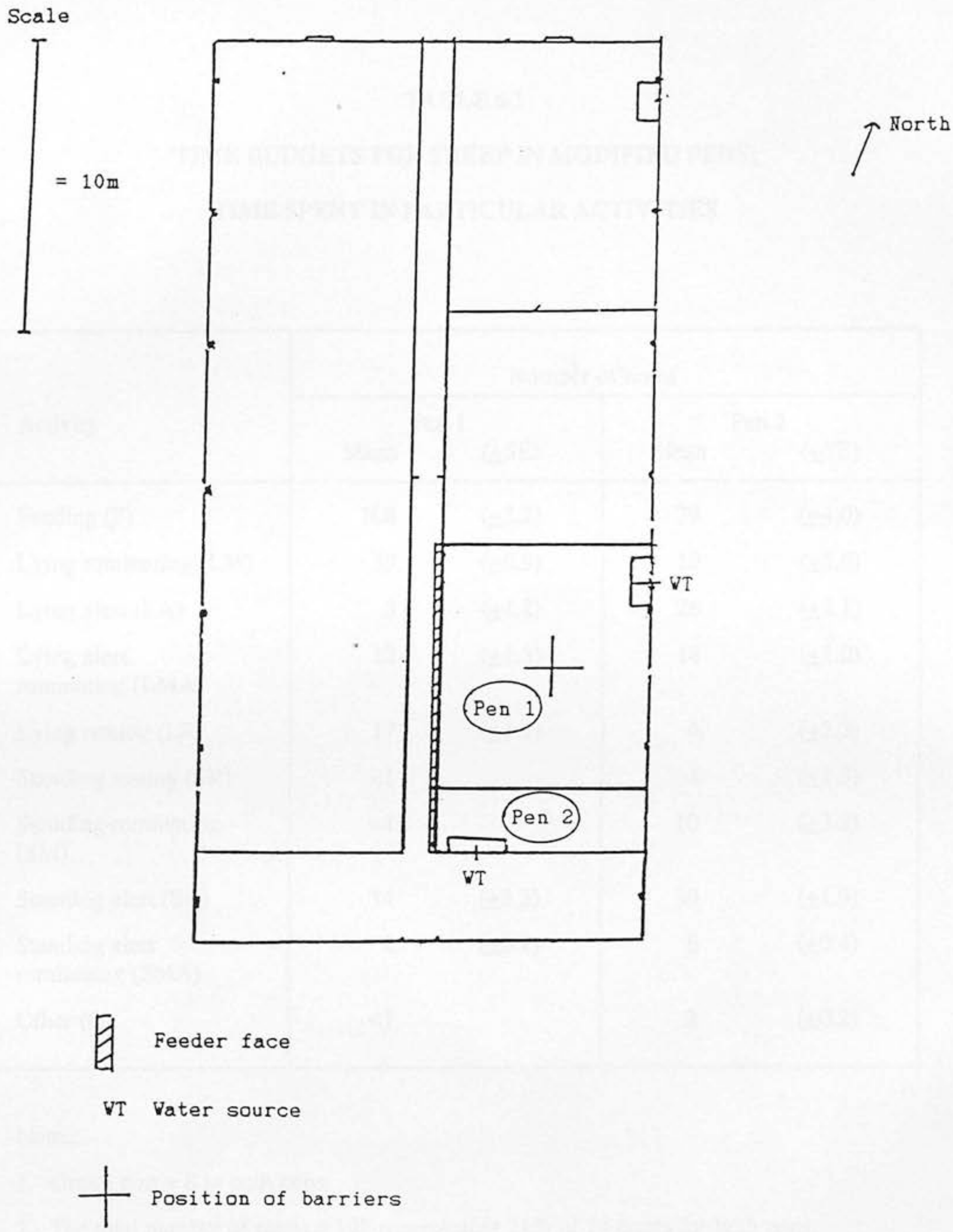


TABLE 6.1

TIME BUDGETS FOR SHEEP IN MODIFIED PENS;

TIME SPENT IN PARTICULAR ACTIVITIES

Activity	Number of scans			
	Pen 1		Pen 2	
	Mean	(±SE)	Mean	(±SE)
Feeding (F)	108	(±3.2)	79	(±4.0)
Lying ruminating (LM)	39	(±0.9)	19	(±3.6)
Lying alert (LA)	3	(±1.2)	26	(±2.1)
Lying alert ruminating (LMA)	12	(±1.3)	18	(±1.0)
Lying resting (LR)	17	(±1.1)	4	(±2.2)
Standing resting (SR)	<1		4	(±1.3)
Standing ruminating (SM)	<1		10	(±3.2)
Standing alert (SA)	14	(±3.3)	30	(±1.9)
Standing alert ruminating (SMA)	1	(±0.2)	6	(±0.4)
Other (O)	<1		2	(±0.2)

Notes:

1. Group size = 8 in both pens.
2. The total number of scans = 198 representing 21% of 24 hours for both pens.
3. <1 means that the mean calculated was not significantly different from zero (using SE and $p<0.05$)

TABLE 6.2

TIME BUDGETS FOR SHEEP IN MODIFIED PENS;

TIME SPENT IN COMBINED ACTIVITY CATEGORIES (%)

Activity	Pen 1	Pen 2
Feeding (F)	54	40
Ruminating (LM+LMA+SM+SMA)	28	26
Resting (LR+SR)	9	4
Lying (LM+LMA+LR+LA)	35	33
Standing (SR+SM+SA+SMA)	11	25
Alert (LMA+SA+SMA+LA)	18	40

Note: Animals are also standing and alert while feeding.

The pattern of feeding and lying behaviour for both groups is shown in Figures 6.2 and 6.3 respectively. For the larger pen (Pen 1) there is considerable allelomimicry and some daily pattern seen, which may be associated with daylength, in the same way as that for the Outdoor Sheep in Extensive Conditions, with two major daily bouts of feeding alternating with lying. For the smaller pen (Pen 2), there is no such allelomimicry or daily pattern seen, the sheep here behaving as do those kept indoors in typical housing conditions, with a few animals feeding and the rest lying or (standing) most of the time.

The animals used the pen edges and barriers primarily for lying resting, as of all lying resting sheep, a significantly greater proportion (at $p<0.05$) were found within sheep reach (1m) of these for both pens (chi^2= 8.71 and 6.22 for pens 1 and 2 respectively and df = 2 for Pen 1 and 1 for Pen 2). In Pen 1 there was no significant difference between the use of the edges or barrier areas (chi^2=3.1 df=1) with the distribution of lying sheep 59% by the pen edge and 42% by the barriers.

The mean area occupied by the sheep (calculated as described previously in Figure 2.6) is given in Table 6.3. Over all activities this was not significantly different ($p<0.05$) from the maximum space available in either pen, but for lying sheep this was slightly less in Pen 1. This means that generally in both pens the animals are making use of all of the available space, although those in the larger pen are lying together closer on average than absolutely necessary.

FIGURE 6.2

PATTERN OF FEEDING BEHAVIOUR OF INDOOR SHEEP

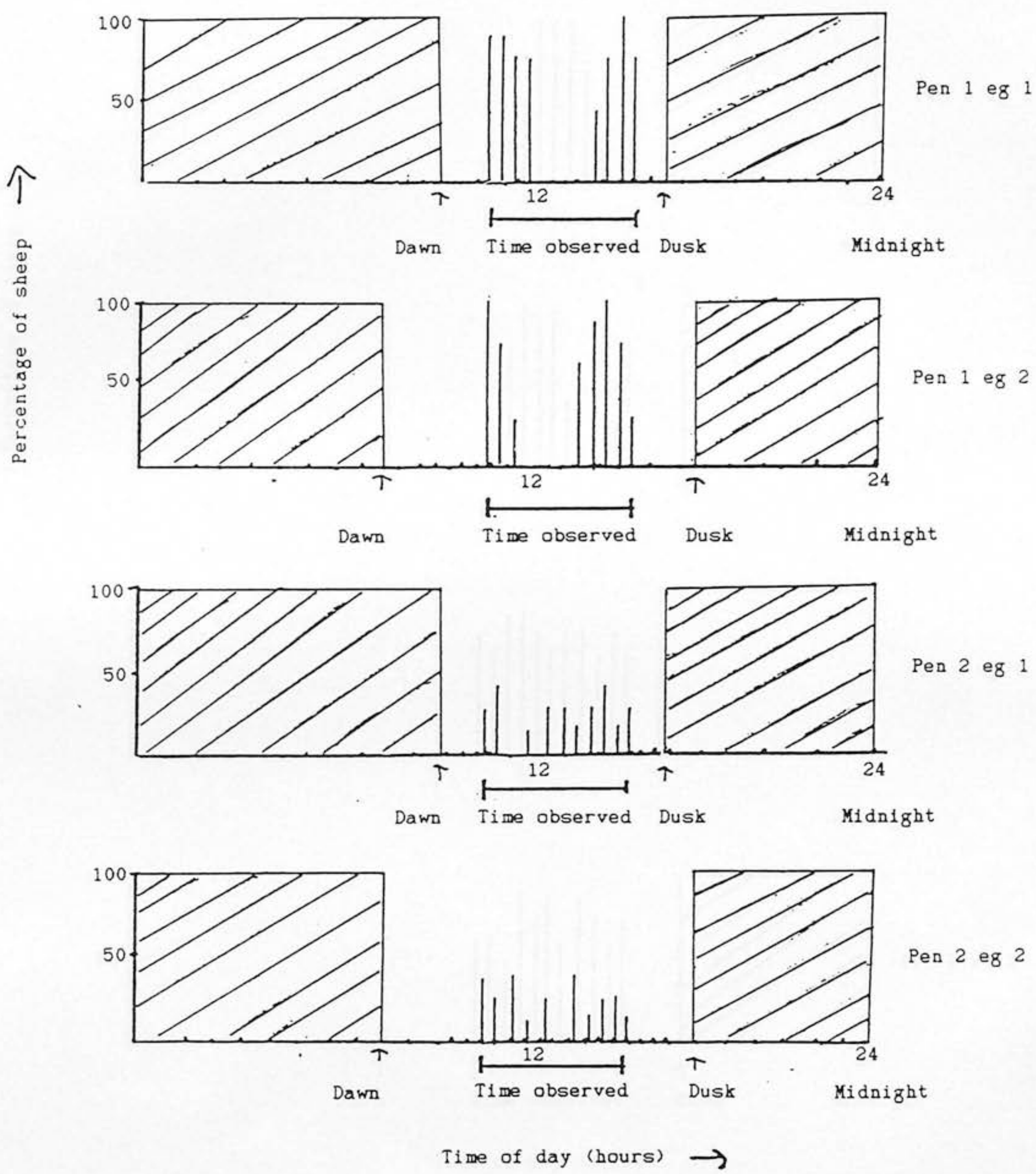


FIGURE 6.3

PATTERN OF LYING BEHAVIOUR OF INDOOR SHEEP

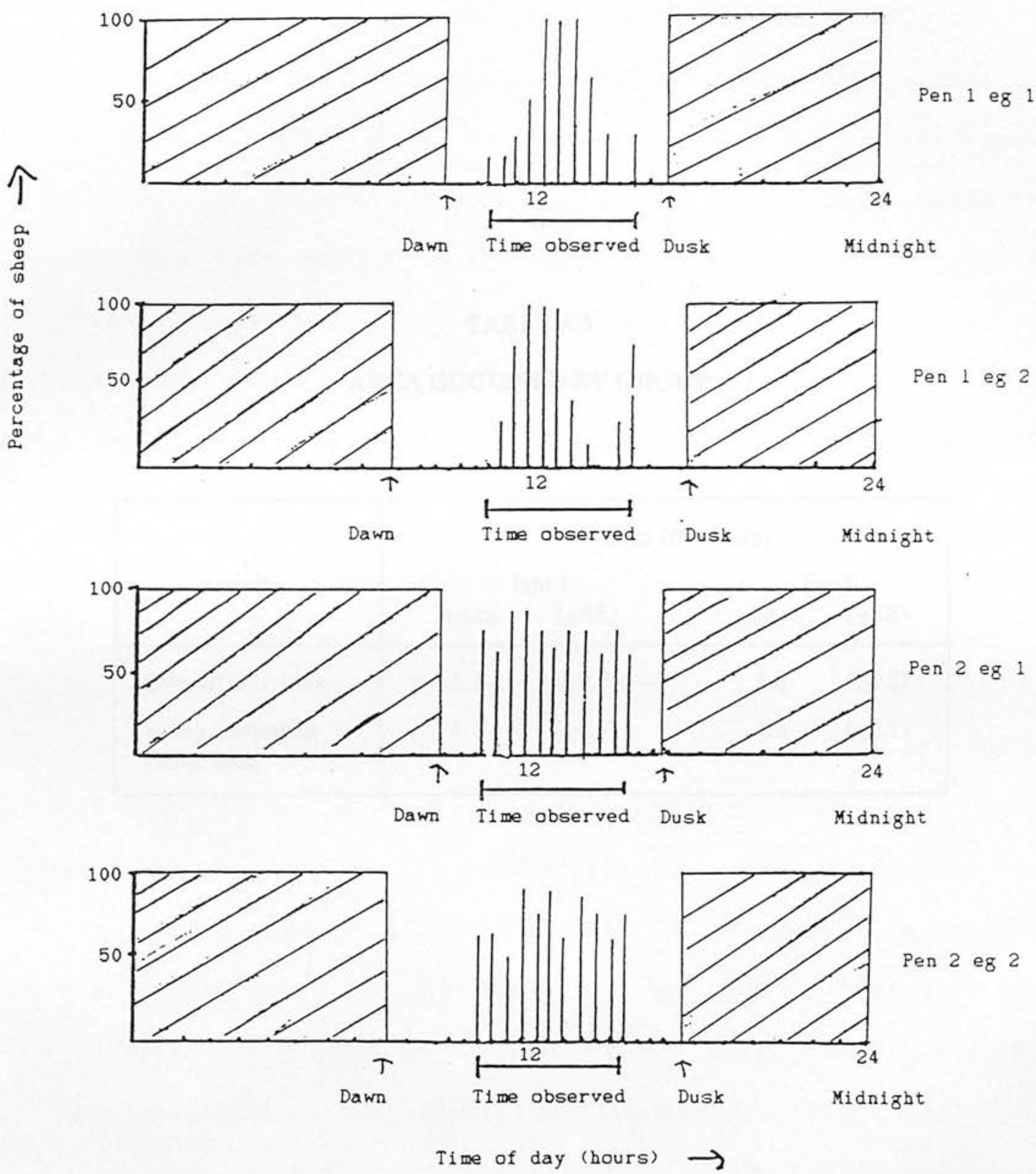


TABLE 6.3

AREA OCCUPIED BY GROUP

Activity	Area (m^2/sheep)			
	Pen 1		Pen2	
	mean	(±SE)	mean	(±SE)
Overall activities	5.2	(±0.9)	1.8	(±0.2)
Lying, resting or ruminating	4.1	(±0.7)	1.8	(±0.1)

The distances between sheep and their orientation towards each other (measured as described previously by Figure 2.4) is given in Table 6.4 and Table 6.5. Most (see modal range) in both groups fed parallel probably due to the structure of the feeder face rather than any 'preferrance' for this relative orientation by the sheep. Most (see modal range) in both groups tended to lie more or less at right angles as seen in other indoor sheep, although for those in the smaller pen (Pen 2) the mean figure is less than this probably due to their lying along the pen sides when possible, thus tending more towards a parallel orientation with each other. No significant relationship was found between these distances and orientations over all activities (r= 0.08 and 0.02 for pens 1 and 2 respectively, N=392 $p<0.05$ for both pens).

The amounts of aggressive interactions and the distribution of these over various resources is given in Table 6.6 and Table 6.7 respectively. Most of these occurred over feeding and lying space, and there were significantly more ($p<0.05$) aggressive interactions seen in the smaller pen. It is interesting that in the larger pen (Pen 1) with the barriers providing extra preferred lying areas as well as overall extra space there are more interactions over access (or movement within the pen) than lying space, while most occur as for other indoor sheepover feeding space. For the smaller pen (Pen 2) again most interactions occur over feeding space, with the greater number of the rest over lying space. The relative amount of competition for access in comparison to other resources is similar in both

TABLE 6.4

DISTANCES BETWEEN SHEEP IN VARIOUS ACTIVITIES

Activity	Mean distances in metres (±SE)			
	Pen 1		Pen 2	
Both feeding	1.6	(±0.32)	0.5	(±0.24)
Both lying	1.9	(±0.19)	1.2	(±0.29)
One feeding, other lying	4.8	(±0.40)	3.3	(±0.41)

TABLE 6.5

ANGLE OF ORIENTATION OF SHEEP IN VARIOUS ACTIVITIES

Activity	Mean angle of orientation (±SE) and [modal range]					
	Pen 1			Pen 2		
	mean	(±SE)	modal range	mean	(±SE)	modal range
Both feeding	12	(±3.1)	[10-19)	9	(±0.09)	[10-19]
Both lying	83	(±4.7)	[90-99]	32	(±4.1)	[80-89]
One feeding, other lying	122	(±5.1)	[120-129]	101	(±5.2)	[100-119]

TABLE 6.6

NUMBERS OF AGGRESSIVE INTERACTIONS, THREATS AND BUTTS

Activity scored	Mean number per sheep per hour (±SE)			
	Pen 1		Pen2	
Number of interactions	0.02	(±0.11)	1.3	(±0.41)
Number of threats	0.05	(±0.09)	2.1	(±0.22)
Number of butts	0.01	(±0.07)	1.5	(±0.36)

TABLE 6.7

DISTRIBUTION OF AGGRESSIVE INTERACTIONS
OVER VARIOUS RESOURCES

	% number of interactions	
Resource	Pen 1	Pen 2
Feeding space	63	49
Lying space	15	31
Access	21	19
Water	<1	1
Unknown	<1	<1

pens, although as shown in Table6.6 the actual amount of all interactions, including those over access, is much greater in Pen 2.

In general the results for the pen modified by group size only are very similar to those found in typical housing conditions as described previously, and the results for the pen modified by increasing space and the inclusion of barriers are similar to those for sheep kept outdoors in extensive conditions, as described previously. A more detailed comparison is discussed later when looking at the overall effects of housing on behaviour as shown by consideration of all of the experimental work. Briefly, however, the sheep in the modified larger pen are physically much closer together and tend to spend less time feeding and more time alert than those outdoors. The change in feeding time could simply be an effect of being fed silage, with its generally higher nutrient density, rather than grass and hay. While the modifications do reduce aggressive interactions, the major factor suggesting a decrease in welfare when housed, a relatively high level of alertness is still seen in sheep in this modified pen. With the lack of aggressive competition seen here this is unlikely to be due to the increased need for awareness of closer and potentially aggressive rivals. It may be a combination of the effects of smaller group size and the enclosed nature of the pens, as the sheep were generally seen to be more alert in areas offering less expansive views outdoors.

CONCLUDING POINTS

1. Modifying the indoor sheep by reducing group size does not significantly affect behaviour in general, although relatively high levels of alertness are seen in this smaller group. This means that comparisons between the smaller groups used outdoors and the larger groups used indoors is still valid.

2. Modifying the indoor sheep by giving an extra $5m^2$ per head and the inclusion of solid non see-through barriers in the centre of the pen does significantly reduce the amounts of aggressive competition seen and allow for time budgeting similar to that seen in extensive conditions although the sheep are much closer together than seen outdoors. Relatively high levels of alertness however are still seen and this suggests that the enclosed nature of the housing environment may be a major cause of this.

GENERAL DISCUSSION

Before proceeding to discuss points relevant to animal welfare, it is necessary to first discuss some of the shortcomings in the present work. Due to financial restrictions, it was necessary to use sheep involved in other experiments. This meant that there were a number of practical difficulties in controlling for various factors in these experiments. The animals were grouped according to a variety of criteria such as weight and condition score, and otherwise penned randomly. This meant that factors such as age and history of housing or other husbandry practices could only be assumed to be evenly or randomly distributed amongst the groups. Where observations were required on animals over a period of time, there were no guarrantees that the group would contain the same individuals for the whole length of that time. The time spent observing the animals was limited to times when a variety of husbandry proceedures would not be being carried out. There was no choice of housing as such, as we had to make use of whatever space was free or already allotted to sheep housed for other experiments, and the arrangement of pens within the sheds used did not alwaysto allow a similar physical environment for each group. For example, some pens were near to open doors, in some the sheep had other sheep in view while others did not. For the outdoor observations on sheep in extensive conditions only a few sheep were available to us, and only one different area in each of the years when this was done. It would have been ideal if the same animals could have been observed in each situation, so that the effects of any individual differences between the animals and the effects of any particular physical peculiarities of each environment could have been examined or at least shown up by the repeated experiment. Penning space and materials was extremely limited and for those experiments where some control was possible, this was occasionally less than ideal. For example, in the Barrier Choice experiment, the pen boundaries were partly made up of the outer walls of the shed and the whole point of the experiment was to investigate which attributes of these were involved in their apparent value as a resource for the lying sheep. This meant that the sheep could continue to use these. The facilities were not available to pen the sheep within the shed in any other way for example using electric fencing which would have been the best way to provide a restricting boundary without any of the attributes of the origonal outer walls. Similarily for the Pen Space and Feeder Length experiment the feed boxes had to be used to provide part of the pen boundaries and be constructed in such a way as to enable me to move them by myself. These practical restrictions meant that the pen shape or even the ratio of pen space to edge length could not be kept constant. This meant that at the very low spacings, feeding sheep obstructed those moving about the pen, and this could have interfered with the animals feeding behaviour. Also when experimenting with modified pens, the small number of sheep available and the limitations on penning materials meant that the pen with 8 sheep at typical farm housing density was very narrow, also restricting movement within the pen and giving a very high ratio of edge length to pen space. There was a general problem with having to use very small numbers of animals in the various groups where I wanted to alter conditions at all with the large amount of individual variation seen. This variation was generally greater for the indoor sheep than for those housed outdoor in extensive conditions, possibly reflecting the differences in the way different individuals reacted to being housed. This meant that there was considerably less chance of finding significant differences between groups. Practical restrictions also limited the isolation of various factors involved when trying out some of the modifications suggested from the results of the previous work. For example, only one such pen with a group size of 8 was available, so that we could not separately test the effect on behaviour of sheep of more space or of extra barriers in the Modified Pens trial. Here again group size and edge length to pen space ratio could not be controlled for. When we wanted to actually manipulate housing conditions as for the Pen Space and Feeder Length trial and for the Barrier Choice trial, time was extremely limiting, as we only had the use of the animals after the tups were removed from the field and before the main bulk of the flock were brought in for the Winter. The timing of this depended on the weather and grass availability. The shed itself was only available after the last of the grain stored in it had been sold, and the exact timing of this depended on grain market price fluctuations. This meant that there was no real time available to allow the sheep to become acclimatised to the experimental conditions and the design had to try to accommodate for habituation and learning over the duration of the experiment. It also meant that as many observations as possible be made in a very short time and this limited the daily routine of these to those of observer endurance. As all experiments had to be carried out over the Winter period, the short daylength also put limitations of visibility on observation time, particularly indoors. Different experiments or sets of observations on sheep over the usual housing period had to be carried out concurrently, again limiting observer time on each. There were also the usual limitations on the accuracy of measurement of distances between sheep and their position relative to various environmental features due to observation, recording and transcription methods. This was likely to be greater for the outdoor sheep as these were observed in much larger areas and from greater distances, and more likely to have an effect on results seen for the indoor sheep as actual distances used were quite small, although their proximity to the observer and the regular distribution of 'landmarks' indoors meant that positional recording of the indoor sheep was likely to be much more accur ate than that of the outdoor sheep.

The behaviour of the sheep in these experiments was generally the same as found by other authors (Cory 1927, Doran 1943, Tribe 1950, England 1954, Cresswell 1960, Arnold 1962, Hunter and Milner 1963, Hunter 1964, Grubb and Jewell 1966, Geist 1971, Jewell, Milner and Morton-Boyd 1974, Squires 1974, Arnold and Dudzinski 1978 , Arnold 1982). It is interesting that this represents a wide variety of breeds, including both wild bighorn sheep (Geist 1971) and the primitive Soay sheep of St. Kilda

(Jewell *et al* 1974) as well as domestic breeds, and also a broad range of climatic and environmental conditions. In this study time budgeting has been considered to be an important means of assessing welfare, and although there was considerable variation seen in the literature the amounts of time spent grazing seen in this study falls within the general range. The daily pattern of behaviour seen in this study was also similar to that generally reported in the above studies. This means that the behaviour of the outdoor sheep in this study can be taken as a reasonable baseline from which to measure the changes in behaviour seen in housed sheep.

There have been few other studies on the behaviour of sheep housed over the Winter under typical farm conditions with which to compare these results. Done (1975) found similar time budgeting in wethers kept in an animal house in large groups. However Done-Currie, Hecker and Wodzika-Tomasewska (1984) found that there was a change seen in time spent in various activities with increasing time spent in an animal house, with animals spending more time standing and observing and less time lying and ruminating as time progressed. As already mentioned, this could not be measured in this study due to lack of observation time with each group. However as the sheep in this study were observed at regular intervals throughout the period of housing, any such changes while not directly measured would have been represented. Furthermore, some comparison can be made with sheep penned for normal husbandry practices such as foot trimming, dosing and sorting. However these practices involve only very short periods of time and density is often much greater than that used for over-wintering. For example Hutson (1984) looked at spacing, lying position and orientation of sheep kept in pens with either open or covered sides and found that when the pen sides were covered the sheep tended to lie next and parallel to the pen edges as found in this study.

Comparison of the behaviour of the indoor and outdoor sheep in this study indicates that the main effects of housing on the behaviour of the sheep, apart from the obvious increase in the proximity of other sheep and feeding on silage rather than grazing are an increase in the amount of time spent alert and standing particularly while ruminating, a decrease in time spent lying and resting, a decrease in the allelomimicry of feeding and lying behaviour and a significant increase in the amount of aggression seen. There was also a change seen in the nature of the aggressive interactions seen; that seen indoors involving on average more butts per interaction. When penned individually, the behaviour of housed sheep is found to be even more disturbed including a high proportion of abnormal behaviours (Done-Currie, Hecker and Wodzika-Tomasewska 1984 and Marsden and Wood-Gush 1986).

These behavioural changes in housed sheep have implications for their welfare. Hughes and Duncan (1989) suggest that the feedback from the performance of a behaviour may be as important as the goal. Considering this concept in relation to housed sheep, the changes in time budgeting seen in this study may be detrimental to welfare. Although the sheep indoors could actually perform all of the activity patterns seen in sheep outdoors in more extensive conditions, the amount of this is altered and so there will be a change in the amount of feedback from the performance of the activity. For example, the changes in time spent feeding, walking and ruminating will alter feedback specific to these activities. The lack of ability to feed and lie and rest together may also cause some distress, as there is a high degree of allelomimicry seen in their behaviour in extensive conditions. Indoors there is considerable competition for feeding and lying space which could to some extent be alleviated by staggered feeding sessions although the continued competition shows that this is not the option accepted easily by the sheep, the decrease in allelomimicry seen indoors being largely due to physical necessity. This pattern of feeding, in more short bouts seen indoors may on the other hand in some way compensate for some aspect of grazing activity involving walking and stopping and starting ingestion, and allow individuals to vary the exact area from which they feed. The increase in alertness seen indoors could be considered evidence of a lack of welfare in the same way, but could also be due to a variety of reasons which would not in themselves represent lack of welfare. For example, it could be due to an increased need for awareness of other sheep in such close proximity or searching for space. On the other hand it could be an attempt to maintain predator surveillance and the increase seen be due to their being split up into smaller groups. It could also be evidence of a decreased threshold of stimulation for visual stimulation, and as such be a causal factor in the increase in aggression seen. Only in this latter case could it be said to be direct evidence of lack of welfare. This may also be involved in the heightened panic response often seen in housed sheep when disturbed, in which the group push and crush each other into a corner of the pen away from the source of the disturbance. This in itself seems detrimental to welfare. It may be that the heightened response in some way compensates for the relative lack of frequency of disturbance. A certain amount of use may be required to maintain the coping systems, as seen for example in the physiology of the supra-adrenal endocrine system, and in this way some substitution of stressors may be useful in the maintenance of an effective response. The relative merits of frequent chronic distress and sporadic acute distress remain to be assessed from the point of view of the welfare of the sheep. Lawrence and Wood-Gush (1982) found that lambs foraging a high crop looked up more and fed closer together in more clumped groups than those with a less restricted visual field. In another study, Risenhoover and Bailey (1985) found that Bighorn sheep avoided areas of poor visibility. These results suggest that sheep prefer to have good long range visibility when feeding. In addition to this a commonly reported feature of the sites chosen by sheep in which to camp at night is a wide view, and so they may find the enclosed nature of common housing anxiety provoking hence the increase in levels of alertness seen. The high levels of aggression seen seem obviously to indicate a lack of welfare for the animals on the receiving end of the threats and butts seen. It is the more successfully competitive sheep which tend to initiate and win all aggressive competitions. It is therefore these individuals which lie predominately in the more favoured areas at the back of the pen next to the wall and other edges or barriers. These areas are generally those in which an animal is less likely to be disturbed due to their out of the way position. This suggests that the instigators and winners of aggressive interactions prefer areas where these interactions are less likely to occur. This may be because they also find such interactions aversive. The ferocity of these interactions often involving repeated butting or kicking in the flank and belly region may contribute to the high incidence of dystokia seen indoors. A general increase in the levels of distress seen in these conditions may contribute to the relative increase in incidence of disease seen in housed sheep by increasing their suseptibility to the heightened disease load (Halpin 1975, Webster 1983 and Rogers 1985). The unequal use of resources by individuals may also contribute to a lack of welfare in this respect. For example, the less competitive sheep often lie on wet, trampled straw soiled with faeces and have less time at the feeding face. Those which are more successfully competitive chose areas to lie which although they have cleaner, drier and warmer straw are less well ventilated at sheep height. For these reasons various individuals may be more suseptible to disease particularly of a respiratory nature, a common problem in housed sheep. An increase in the amount of time spent standing on soft, wet, acidic bedding may contribute to foot problems leading to lameness. However the provision of warm comfortable bedding, over a solid floor, which can in itself be chewed or played with has been shown to alleviate some behavioural problems, particularly in decreasing the incidence of oral stereotypies in other housed animals (eg. Fraser 1975) and sheep housed in groups on slats began to pull each other's wool whereas those in the same experimental conditions with straw did not (Kallweit *et al* 1988). Although no other sorts of floor or bedding were examined in this thesis, it would seem that on balance deep-litter straw over a solid floor is suitable for sheep from a welfare point of view, providing that this is regularly topped up and the animals are not allocated lying space in areas of frequent use likely to quickly become dirty and trampled, such as that in fromt of the feeding face. In such conditions, the concentrate feed which was a source of considerable aggressive competition could be given sprinkled in the straw, avoiding the rush, jostling, butting, and allowing more equal distribution of the feed amongst individuals. The searching for this highly prized resource might also improve welfare by providing feedback of a form associated with normal grazing activty. It is interesting that the outdoor sheep spent the greater part of their feeding time grazing, in conditions in which there was relatively little nutrient value in the grass compared with the hay which was constantly available. Broom and Arnold (1986) also found that sheep did not forage optimally on pasture even when feed availability was extremely low. This may have been due to a need for some other specific feedback associated with grazing such as walking, looking around or concerned with feedback from working for their food as found in fowl (Duncan and Hughes

1972). It could also be an attempt to vary their diet or improve its palatability. The monotonous nature and relative ease of availability of food given indoors could for these reasons be considered counter to welfare. It is interesting that the sheep will go to drink and scratch independently outdoors. Casual observation during the work of this thesis showed that scratching the top of their back was the primary way in which the sheep moved or damaged boundary fencing, hedges, and hay racks. As sheep do not have the same extent of social grooming behaviour seen in other animals, probably because of the nature of their woolly coat, scratching is an important aspect of body care. The facilities allowing them to easily scratch themselves and the top of their backs in particular could be incorporated into pens indoors, possibly simply by angular bars or posts fixed at an angle to solid walls or as used to support pen boundaries or internal barriers. This ought not only to improve the welfare of the animals but also alleviate some of the practical problems resulting from the destructive effects of their scratching habits.

In conclusion it is apparent that the housing of sheep involves many risks to their welfare as assessed using behavioural techniques. They respond to social, physical and feeding restriction in the same way as other animals, giving rise to similar concern for their welfare. Current typical farm housing methods are not as far removed from the ideal as is the case for other livestock such as veal calves, battery hens and tethered sows. However, there is room for considerable improvement and, although the practical work of this thesis was rather limited, involving many uncontrolled factors, very low animal numbers and was without repetition to check for the effects of individual variation, or acclimatisation and learning by the animals used, the following practical recommendations for the housing of sheep are proposed:

Recommendations based on the results of this study;

1. When allocating pen space it should be remembered that aggressive competition is considerably reduced by giving the animals more space up to $7m^2$ per head (see pages 134 - 136). There was no evidence found to suggest that increases over $7m^2$ per head had any similar significant effect (see page 165), although the sheep did make use of extra space up to $12m^2$ per head when this was available (see page 124).

2. When initially brought in the sheep should be penned at the density they will finally be allocated. Penning at gradually increasing density in particular should be avoided. (see page 165)

3. Feeding space should allow all animals to feed together and not be made up of separate areas, giving if possible up to 0.75m per head. The area taken up by feeding sheep should not be included in the pen space allocated to the animals (see page 166).

4. Where possible the pen shape should be such that there is a high proportion of edge length to overall space. This could be achieved by using long narrow pens and by the inclusion of

solid non see-through barriers within the pen while avoiding any impediment to sheep movement within the pen (see page 103). The barriers could also be designed in such a way as to allow their progressive incorporation into lambing pens eg. by using the cross shape as used in the experimental work of this thesis which also enables the barriers to be free standing and so be relatively mobile and easily erected in any building.

Recommendations based on casual observation during this study;

5. The flooring (deep-litter straw over solid concrete) used in this study did not cause any welfare problems.

6. Drinking sources need only allow for one or two animals within the group to drink at the same time, but care should be taken in the siting of these to give clear easy access for the sheep avoiding positions where a drinking animal will block the movement of sheep within the pen.

7. Scratching bars should be provided and could be incorporated into the support structure of the pen boundaries or barriers.

8. The housing could allow good long range visibility for the sheep, as they appear to become more anxious and reactive to disturbance when enclosed, and in their natural environment seek refuge when frightened and lie at night in areas affording such a view (see page 72).

9. The diet should be varied and given in a form and way requiring more work to be done to obtain adequate nutrition. In particular some thought should be given to the distribution of

the concentrate feed as this is a cause of considerable aggressive competition amongst the sheep. For example sprinkling this over the straw or mixing it in with the forage fed, and giving a smaller proportion of the daily ration more times per day would help to reduce this major source of competition, allowing a more even distribution of the group ration to each individual and might also reduce any unsatisfied motivation from a lack of grazing behaviour.

Recommendation based on the literature on sheep behaviour;

10. From the point of view of allowing sheep to maintain their natural social behaviour, they could be kept in large groups, where possible animals being familiar with each other, and of the same sex and similar age, as this is their habit in the wild and that adopted by domestic sheep in extensive conditions.

The cost of these recommendations may be prohibitive and recent trends in agricultural policy may mean a decline in the intensification of the sheep industry, removing the economic incentives to over-winter sheep indoors. The extent of the physiological adaptation of sheep to their own ecological niche and the behavioural responses to housing seen in this study suggests that Winter housing may create more welfare problems that it solves, and perhaps further attention should be given to the provision of shelter in the field built and sited in such a way that the sheep will freely use it when required?

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APPENDIX A

ETHOGRAM FOR OUTDOOR SHEEP

This list contains the behaviour patterns actually observed in the sheep used in this particular study.

Each behaviour category has a two letter summary code. For some behaviours a set of superscripts was also included to give detailed postural information and, where it was appropriate, subscripts were used to provide additional information, eg. for a behaviour such as scratching to indicate the part of the animal being scratched and with what.

All possible sub- and super- scripts are given first.

SUPERSCRIPTS

m1	Ruminating
m0	Not ruminating
f1	Forehead/chin angle (of line between poll to mid jaw with a vertical line drawn through poll) of 0 to 45 degrees
f2	Forehead/chin angle of 45 to 90 degrees
f3	Forehead/chin angle of 90 to 135 degrees
f4	Forehead/chin angle of 135 to 180 degrees
f5	Forehead/chin angle of 0 to -45 degrees (where 0 degrees is parallel to the vertical line through poll, and +ve is in an anticlockwise direction)
e1	Eyes open
e2	Eyes closed
e3	Eyes partly open, partly closed
r1	Ears up and forward
r2	Ears up and back
r3	Ears down and forward
r4	Ears down and back (where forward or back mean tip of ear is in front of or behind a line drawn vertically

	through the base of the ear, and up or down mean that the tip is above or below a line drawn horizontally through the base of the ear) If the ears are in different positions, two digits are used; the first denoting the right ear and the second the left ear.
n1	Neck angle (ie of line between withers and tail and that between poll and withers) of 0 degrees
n2	Neck angle of 0 to 45 degrees
n3	Neck angle of >45 degrees
n4	Neck angle of 0 to -45 degrees
n5	Neck angle of <-45 degrees (where +ve is anticlockwise)
t1	Tail angle (ie of line between withers and point of tail and line between point and tip of tail) of 0 to 45 degrees
t2	Tail angle of >45 degrees
t3	Tail angle of 0 to -45 degrees
t4	Tail angle of <45 degrees
t5	Tail wagging
t6	Tail clamped

<u>SUBSCRIPTS</u>

h	hay
u	trough
g	grass
c	space to graze
l	space to lie
r	rack

d	hedge(vertical pieces)
t	tree trunk >6" across
y	young tree <6" across
b	non vertical piece of tree or hedge
m	stream
a	access space
o	log
p	fence post
s	stump
n	stone
e	sheep(1-8 to identify individuals)
d	disturbance
x1,2,3,4,5,6,7,8,9,0	muzzle,sub-orbital gland, side of face,under jaw,forehead, behind ear, neck, shoulder, belly flank, rump of self
z1-10	as for x1-10 of another sheep

BEHAVIOUR PATTERNS

FT	feeding from trough
FR	" " hayrack
FG	" " ground
ZB	grazing with more biting than walking (measured temporally)
ZW	grazing with more walking than biting (measured temporally)
ZO	feeding and walking on non grassy ground where feeding takes most time
DM	drinking
SD	standing (posture denoted by superscripts)

LG	leaning
WT	walking towards resource (incl. sheep)
WF	walking from resource (incl. sheep)
WK	walking where unsure of "purpose"
WO	walking and feeding on non grassy ground where walking takes most time (cf ZO)
RT	running towards resource
RF	running from resource
RN	running where unsure of "purpose"
JU	jumping up a bank
JD	" down "
LY	lying (posture denoted by superscripts)
DF	defecation
UR	urination
PW	paw with foreleg
SF	sniff
PS	push
RB	rub (usually = scratching) gently
RH	rub hard/fast
RV	rub very hard/fast
BT	butt
CW	chew
LK	lick
SH	shake head
SB	shake body
VI	vocalisation initiated
VR	" in reply

[extra subscripts were used here to indicate pitch(1,2or3 for low,medium or high),call length(approx.secs),call frequency(approx.secs call/approx. secs. interval /etc)]

"Standing" is defined as weight supported by all four feet while stationary

"Lying" is defined as weight supported by none of feet while stationary

(no intermediate case was seen in this study)

"Walking" is defined as movement, primarily in a horizontal direction, with only one foot off the ground at any one instant.

"Running" is defined as movement, primarily in a horizontal direction, with more than one foot off the ground at any one instant.

"Jumping" is defined as movement, primarily in a vertical direction with more than two feet off the ground at any one instant.

APPENDIX B

ETHOGRAM FOR INDOOR SHEEP

This list contains the behaviour patterns actually observed in the sheep used in this particular study.

Each behaviour category has a two letter summary code. For some behaviours a set of superscripts was also included to give detailed postural information and, where it was appropriate, subscripts were used to provide additional information, eg. for a behaviour such as scratching to indicate the part of the animal being scratched and with what.

All possible sub- and super- scripts are given first.

SUPERSCRIPTS

m1	Ruminating
m0	Not ruminating
f1	Forehead/chin angle (of line between poll to mid jaw with a vertical line drawn through poll) of 0 to 45 degrees
f2	Forehead/chin angle of 45 to 90 degrees
f3	Forehead/chin angle of 90 to 135 degrees
f4	Forehead/chin angle of 135 to 180 degrees
f5	Forehead/chin angle of 0 to -45 degrees (where 0 degrees is parallel to the vertical line through poll, and +ve is in an anticlockwise direction)
e1	Eyes open
e2	Eyes closed
e3	Eyes partly open, partly closed
r1	Ears up and forward
r2	Ears up and back
r3	Ears down and forward
r4	Ears down and back (where forward or back mean tip of ear is in front of or behind a line drawn vertically through the base of the ear, and up or down mean that the tip is above or below a line drawn horizontally through the base of the ear) If the ears are in different positions, two digits are used; the first denoting the right ear and the second the left ear.

n1	Neck angle (ie of line between withers and tail and that between poll and withers) of 0 degrees
n2	Neck angle of 0 to 45 degrees
n3	Neck angle of >45 degrees
n4	Neck angle of 0 to -45 degrees
n5	Neck angle of <-45 degrees (where +ve is anticlockwise)
t1	Tail angle (ie of line between withers and point of tail and line between point and tip of tail) of 0 to 45 degrees
t2	Tail angle of >45 degrees
t3	Tail angle of 0 to -45 degrees
t4	Tail angle of <45 degrees
t5	Tail wagging
t6	Tail clamped

SUBSCRIPTS

s	straw
u	trough
g	silage
f	space to feed
l	space to lie
c	pen boundary (feeder face)
b	pen boundary (back wall)
d	pen boundary (side wall, pen division)
p	post
a	access space
e	sheep(1-8 to identify individuals)
r	disturbance
x1,2,3,4,5,6,7,8,9,0	muzzle, sub-orbital gland, side of face, under jaw, forehead, behind ear, neck, shoulder, belly flank, rump of self
z1-10	as for x1-10 of another sheep

BEHAVIOUR PATTERNS

FT	feeding from trough
FF	" " feeder face
FG	" " ground
FS	feeding on straw (with more time feeding than walking)
FW	feeding on straw (with more time walking than feeding)
DM	drinking
SD	standing (posture denoted by superscripts)
LG	leaning
WT	walking towards resource (incl. sheep)
WF	" from "
WK	walking where unsure of "purpose"
RT	running towards resource (including other sheep)
RF	" from resource (including other sheep)
RN	" where unsure of "purpose"
JT	jumping over trough
JS	" " sheep
LY	lying (posture denoted by superscripts)
ST	sitting (posture denoted by superscripts)
DF	defecation
UR	urination
PW	paw with foreleg
PK	kick with foreleg
SF	sniff
PS	push
RB	rub (usually = scratching) gently
RH	rub hard/fast
RV	rub very hard/fast
TT	threat
BT	butt
CW	chew
LK	lick
SH	shake head

SB shake body

VI vocalisation initiated
VR " in reply

[extra subscripts were used here to indicate pitch(1,2or3 for low,medium or high),call length(approx.secs),call frequency(approx.secs call/approx. secs. interval /etc)]

"Standing" is defined as weight supported by all four feet while stationary

"Lying" is defined as weight supported by none of feet while stationary

"Sitting" is defined as weight supported by forefeet while stationary

"Walking" is defined as movement, primarily in a horizontal direction, with only one foot off the ground at any one instant.

"Running" is defined as movement, primarily in a horizontal direction, with more than one foot off the ground at any one instant.

"Jumping" is defined as movement, primarily in a vertical direction with more than two feet off the ground at any one instant.

APPENDIX C

OBSERVATION RECORDING TECHNIQUES

FOCAL ANIMAL SAMPLING

This involves the continuous observation of one animal, referred to as the focal animal, for a predetermined period during the day. The animals and periods are chosen so that all individuals are observed over a variety of times of the day, to attempt to provide a sample representative of each individual's activity throughout the day. The details of its behaviour are recorded in chronological order. The first record is of the time at the start of the recording period, and a note of the animal's behaviour at that time. A previously determined code is used to enable detailed, accurate and consistent recording (as in Appendices A and B). The animal is watched until its behaviour changes, and the time of the change and the new activity recorded. If any activity lasts for some time, a measurement may be made of the nature and rate of that activity eg number and rate of biting, chewing, steps while grazing or of regurgitation and chewing while rumunating etc. The position of the animal within its enclosure can also be noted by plotting its position on a set or prepared maps of the area using consecutive numbers to represent the animal, say every 30 seconds, or each minute. The list continues until the end of the predetermined period, when recording stops. This technique allows very accurate and detailed information to be gathered for short periods of time.

SCAN SAMPLING

This involves the recording of the behaviour of a group of animals at any given instant. At a predermined instant, eg. every ten minutes, the activity of each individual is noted. To enable a large group to be dealt with at more or less the same instant, a much reduced abbreviated code is used. For example, behaviour is often denoted simply as grazing, coded by the letter G or lying ruminating, coded by LR etc. This technique allows the behaviour of a large group to be recorded over a long period of time, often the whole day. It is particularly useful when looking at social behaviour or group synchrony, and if recording is made by plotting each individual on a prepared map of its enclosure, eg using a line with an arrow to represent the head, with its identity number and activity code letter beside or encircled with this line, very useful information about the animals' use of their enclosure can be obtained. This technique is most often used to measure the time spent in various activities by each animal (or averaged later to represent the whole group), by assuming that if on 10 out of 20 scan samples that animal was recorded as feeding, for example, it was feeding for 50% of the total observation period ie the time between the first and the final scan sample.

INTERACTION SAMPLING

This involves the recording of specific events occurring within a predetermined time period for a group of animals. It is most often used to look at social behaviour, in particular affiliative or aggressive interactions, but can be used to record any event or specific activity. A list of expected details or variations of the event is initially drawn up and coded, with a code left for any other unexpected events. The codes are arranged in a list across the top of each recording sheet, including a column to record the individual involved, the time of occurrence and any other associated details such as position in enclosure which are relevant to the analysis of the behaviour or event. Each line down the side of the sheet represents one occurrence of any of these events. The rows are filled in by writing in identity numbers, times, and ticking the appropriate column denoting the event. If the sequence of the details is of interest, consecutive numbers instead of ticks can be used. The success of this technique depends largely on meticulous preparation from practice sessions so that all likely eventualities are catered for in the list of coded details. Space should always be left at the left hand side of the page for writing in the details of any unexpected variations which are not coded for. For example, when looking at aggressive competitive interactions, I coded for time of occurrence, identity of instigator, previous activity of instigator, identity of recipient, previous activity of recipient, area of pen where interaction took place, resource involved over which interaction took place , or other reason for interaction if apparent (eg one animal trying to get past another), numbers of threats and butts given by each (using numbers rather than ticks, to record the sequence), urination or dunging by each animal, and the outcome of the interaction, eg displacement of one or other, and subsequent activity of both. When a third or fourth individual became involved, they were easily included as recipient on the next line of the sheet. This technique requires careful preparation and demmands thorough concentration by the observer, but if carried out in short bursts (eg for 10 minutes in every 15 minute period of observation), can be a very accurate and detailed measure of any given activity.